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MARIN COUNTY RESOURCE CONSERVATION DISTRICT

GROUNDWORK

A Handbook for Erosion Control in North Coastal California





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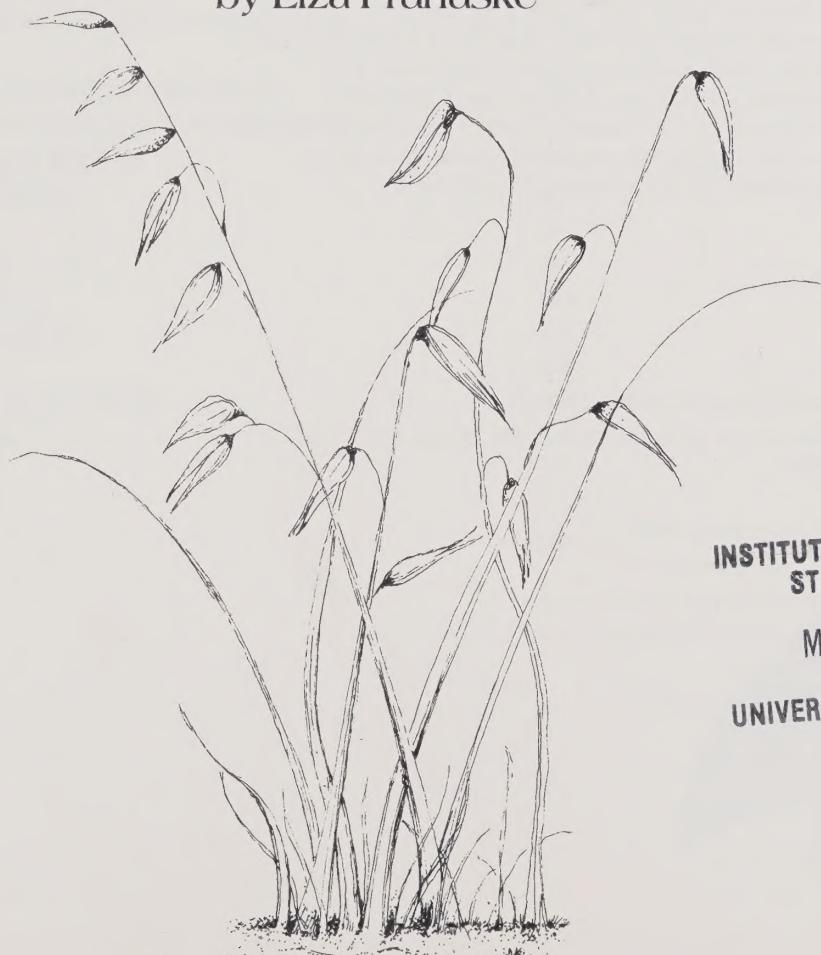
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GROUNDWORK

A Handbook for Erosion Control in North Coastal California

by Liza Prunuske



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Marin County Resource Conservation District

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Forward

This handbook has been prepared for the Marin County Resource Conservation District with funding from the California Coastal Conservancy. The handbook is part of a program aimed at reducing erosion and sedimentation in the Lagunitas Creek Watershed, funded by grants from the Coastal Conservancy, the San Francisco Foundation and the California Department of Fish and Game. This program has been generously supported by volunteer labor, local public agencies and participating landowners.

Resources Conservation Districts (RCD's) were established by the federal government in the 1930 Dust Bowl days to lend a local voice to the Department of Agriculture's new Soil Conservation Service (SCS). Now RCD's function as divisions of state governments with publicly elected boards of directors. In California alone, there are 122 districts; across the country, there are more than 3,000. The purpose of the RCD's is to bring together state, federal and local agencies with private landowners to conserve soil and water. They continue to provide local guidance to SCS on how federal funds and technical assistance are used in their communities. The districts do not make or enforce legislation; they work through cooperation and education.



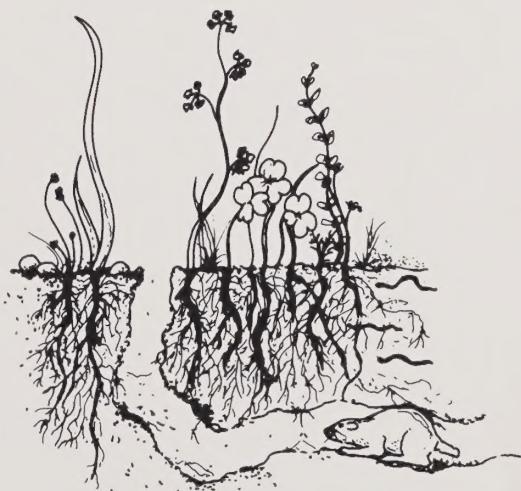
Soil, Erosion and Sediment

Soil is more than that brown mud the dog tracks into the house after a rainstorm. It is an intricate ensemble of living microorganisms, humus (partially and completely decayed organic matter) and inorganic particles worn down from parent rocks. The process from rock to soil is a slow one. An average inch of topsoil, richest of the soil layers in organic matter and the creatures that decompose such material, takes a thousand years or more to form.

As any home gardener knows, soils vary widely in fertility, mineral content, physical structure and the way they react to wind and water. Some soils drain slowly, making them poor choices for unsurfaced roads or septic systems. Others are highly erodible, and the smallest disturbance can lead to a gully or streambank washout.

The type and depth of soil play a major role in determining what kind of plants grow in an area. The plant community in turn affects what species of fish and other animals, both domestic and wild, can live there and how many can survive comfortably.

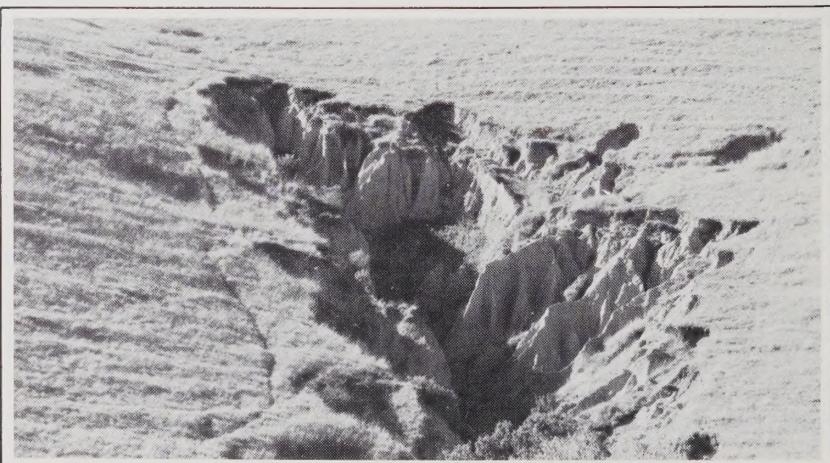
Soil erosion is a natural process. In stable watersheds, the rate of erosion is slow, and natural healing processes can keep up with it. But in many watersheds, human use of the land has accelerated the rate of change beyond nature's short-term healing capabilities—in some places even beyond long-term recovery. The desertification process in the Sahel region of Africa is a dramatic case in point of how altering the balance amongst inherent soil conditions, weather patterns and native plant and animal communities has drastic



repercussions. Closer to home, in the Palouse region of eastern Washington state, 20 bushels of topsoil are lost for every bushel of wheat produced.

The effects of soil erosion are not limited to the site where the soil was lost. The detached soil, called sediment, enters the water system and settles out—at a culvert inlet, in a stream channel, in a lake or in an estuary. Some sediment is needed to bring nutrients and substrate materials to aquatic ecosystems, but too much sediment causes problems. It can reduce the space watercourses have available to hold stormflows, thereby increasing flooding. Fine soil particles fill in wetlands and cement stream bottoms into uniform surfaces that no longer provide nooks and crannies to shelter young fish and the aquatic animals they eat. Erosion and sedimentation are a major cause of the decline of hundreds of animal species, from coho salmon to clapper rails, from oysters to caddisflies. Entire regions of ancient Mesopotamia and northern Africa were slowly abandoned, as sediment clogged the channels that brought water to fields and once-prosperous cities.

Although small erosion problems may not seem significant compared to the loss of whole civilizations, together they contribute vast amounts of sediment to our rivers, lakes and bays. The purpose of this handbook is to show ways to prevent and to repair erosion problems common to northern coastal California, using simple, practical techniques.



PAUL SHEFFER

Four Basic Rules for Preventing Common Erosion Problems

1. **Protect bare soil surfaces.** Vegetation is the best protection because it both absorbs and uses water. Gravel, straw, wood chips and other mulches are also effective. If you use an impermeable substance, such as plastic or concrete, be careful where you direct the runoff. You don't want to fix one erosion problem while creating another!
2. **Don't concentrate water flow unless absolutely necessary.** On undisturbed slopes, water percolates through soil slowly and relatively uniformly. Even during heavy rainfall, runoff that can't be absorbed flows evenly over the ground surface into the nearest drainage. When all the runoff from a single area is focused on one spot, such as by a culvert or a roof gutter, the natural protection of the ground surface is often not sufficient to prevent this extra flow from breaking through to bare soil. If you must focus runoff, protect the outflow area with an energy dissipator, such as rock or securely anchored brush, that will withstand stormflows.
3. **Limit livestock and human use of vulnerable areas.** Livestock and people can exacerbate mild erosion by disturbing vegetation and creating trails that channel the flow. Areas to be especially concerned with include fill slopes, creeks that have abrupt changes in gradient, winter swales, unsurfaced roads, old landslides and any site that shows signs of recent soil loss.
4. **Disturb existing vegetation as little as possible.** Plants hold topsoil, and even subsoil, in place with their roots, regulate the speed of water flowing through and over soil and protect the soil surface, as well as provide cover and food for wildlife. The native plant community is especially well adapted to suit specific soil and rainfall conditions. Once it is disturbed through growing food, harvesting timber or constructing houses, the soil below becomes much more susceptible to erosion. Of course we need to harvest resources and build homes; but if you have a chance to leave native plants intact and keep them healthy, do!



Straw and erosion control netting protect exposed soil.

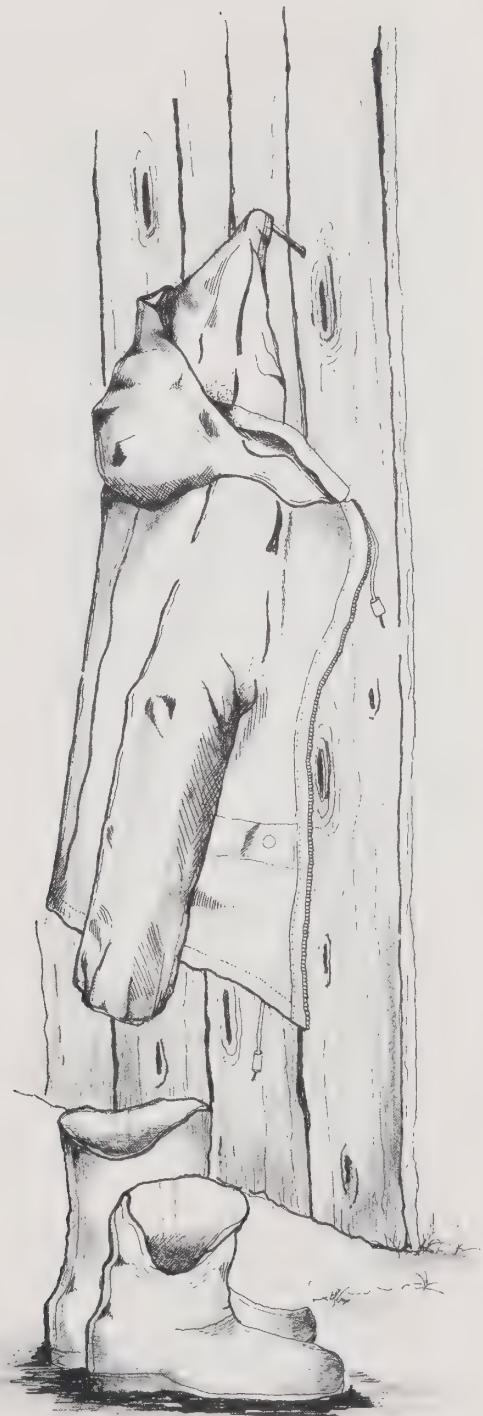


Healing Erosion: General Guidelines

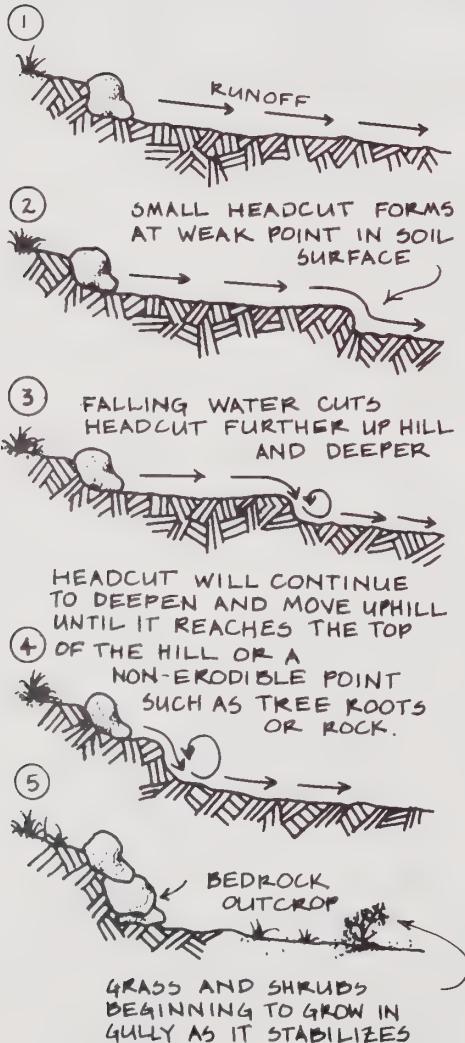
Most erosion problems share the common ingredients of exposed soil, flowing water and an agent, usually human or climatic, that disrupted a pre-existing equilibrium. The following guidelines will help you understand and effectively repair all common erosion problems.

1. **Watch the problem.** The most essential tools for erosion control in northern California are a pair of rubber boots and a good rainsuit. The action happens during the rains. You can see firsthand how problems develop and grow, and you can catch little things before they become catastrophes.
2. **Keep in mind stormflow.** As you plan or execute a repair, especially during the dry season, stand back and visualize what will happen during a heavy storm. Will water shoot out beyond the rock you've placed at the foot of a checkdam? Will it eddy around a gabion and cut a new hole in the streambank?
3. **Work very carefully.** Flowing water is not forgiving. It finds the tiniest crack and undermines the best intentions.
4. **Be patient.** Every site is unique, and it may take years of observation and modification to fine-tune a repair to fit the problem precisely.
5. **Be creative.** For example, sometimes a handful of leaves works better than a truckload of rock to seal a checkdam. Be careful, though, not to add toxins or garbage to the watershed or to create a new problem downstream.

6. Obtain the proper permits. Most structural streambank repair requires permits from the California Department of Fish and Game and your county planning or public works departments. You may also need a permit from the U.S. Army Corps of Engineers for work in stream channels. Gully and road repairs may require county permits. Coastal zone work comes under the auspices of the Coastal Commission. Check with your county planning department or the Soil Conservation Service to find out what permits you need. Chapter 10 lists addresses for state and federal regulatory agencies.



3 Gullies



Gully movement

Gullies in coastal California vary almost as much as beefsteak tomatoes. Depending on soil type, how the gullies were caused, the amount of water flowing into them and the rate of runoff from the surrounding watershed, they range from ruts to junior canyons. Some gullies grow slowly, widening from undercut banks during record rainstorms and recovering during drier years. Other gullies seem to devour land, often spreading into tributary drainages as they race upslope. Because of this variability, it is important to understand some of the basic concepts of gully action so that you can tailor the repair techniques to your particular gully. What works wondrously in one can be ineffective, and frustrating, in another.

Gullies move upslope. Usually they occur in natural drainages, but ditches and the outflow areas from culverts or roof drains can also grow into gullies. The frontline of the typical gully is the primary headcut, the sharp break in slope gradient at the top of the gully. As water falls over the headcut, it continuously erodes the cut face, and the gully expands up the hill. Some gullies have more than one primary headcut, each spreading into a subdrainage.

Secondary headcuts work within the gully by the same action, undermining the gully floor and thereby widening and deepening the channel. Some gullies have relatively uniform bottoms, with no secondary headcuts. Others, often older gullies that have begun to heal and then reopen, stairstep up the slope in a series of mini-gullies. Gullies frequently stop when they come to tree roots or bedrock and then continue on the other side.

Even when all the headcutting is stabilized, a gully can still grow wider as flow undercuts the gully banks. To stop this kind of expansion the banks must be either protected with a

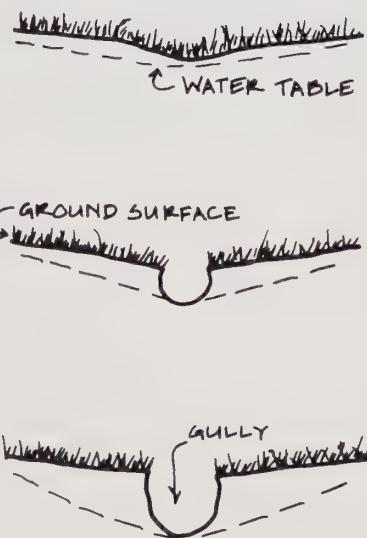
nonerodible armor, such as rock riprap or dense vegetation, or sloped to a gentler angle to diffuse the force of the water over a wider surface.

As gullies deepen, they lower the groundwater table. In rangeland, this in turn can have a profound effect on the surrounding vegetation, often making it easier for hardier weedy species to overwhelm more succulent forage plants.

Before you tackle a gully, always try to figure out what started it and what is making it worse. Does a dirt road above the gully focus water into the gully drainage? If so, your most cost-effective repair may be to modify the road drainage. (See Chapter 5.) Anything that disrupts the natural drainage pattern is a potential culprit. If most of the small drainages within a watershed are gullied, then the problem may be an increase in the rate of runoff due to compaction or a change or loss of vegetation. If feasible, it is wise to address these more fundamental problems before treating their symptoms. Occasionally gullies are one-time events created during exceptionally severe storms. In such cases, you may not find an obvious cause.

The following are steps to follow, in order, for repairing most gullies. Descriptions of specific techniques follow the steps.

1. Try to discover why the gully formed. If possible, address the cause.
2. Stop the headcutting. If your resources are limited, you may have to stop here. Stabilizing the gully head will at least prevent the gully from lengthening. In time, if no active secondary headcuts develop, the gully sides will reach a stable slope and, if a natural seed source is available nearby, eventually revegetate themselves. Headcuts are best stabilized by making the cut invulnerable to erosion by creating a protective armor. In some cases, diverting water from the cut can hasten recovery.
3. Stop the downcutting. If active secondary headcuts within the gully are not stabilized, they may creep upslope and undermine whatever work you have done to repair the primary headcut. Downcutting may be treated by armoring the cuts or constructing checks, either small dams (checkdams) or vegetation, across the gully floor to slow the flow. If you can't construct all the checks needed at one time, start installing them at the lower end of the gully where they won't be undercut by upstream erosion.



Gully impact on groundwater table

PAUL SHEFFER



Gully healed with rock checkdams, grass seeding and willow sprigs

4. **Raise the level of the gully.** Checkdams also allow sediment to settle out in the slower water above the dam. As the floor of the gully rises, the water table also rises, and the banks of the gully become shorter and more stable. Plants are able to take root because the soil stays in place instead of continually washing away.

5. **Slope the banks of the gully back to a stable angle.** With the headcutting and downcutting stabilized, this will usually occur naturally in time. However, sloping the banks and allowing vegetation to become established, either by itself or with a little help, can speed up the recovery process.

If bank erosion is extremely active, the banks should be sloped and stabilized before checkdams are installed. Otherwise, bank failure can expose the ends of the dams, threatening their structural support and allowing water to erode the banks further.

In most gully work, it is important to remember that the structural work, no matter how carefully constructed, is meant to be temporary. Its purpose is to hold the soil still long enough for plants to take over the job. While the gully is recovering, you may have to fence out people or animals so that the vegetation has a fair chance to become vigorous. In the long run, it is cheaper for plants to maintain the gully than for you to have to replace rock or reinforce checkdams. Vegetation, especially in or near a drainage, also provides a haven for wildlife and is invariably more pleasing to look at than even the most artistically placed redwood 2-by-12's.

The final goal of gully repair projects is to transform a sediment-oozing gash into a gentle, well-armored swale that carries winter flows without eroding.

STOPPING THE FRONTLINE: HEADCUTS

Headcuts are hard to stop. By definition, they are the fastest eroding part of most gullies. All the techniques listed below have been used successfully in west Marin, but they are not all appropriate for every headcut. In addition to the factors listed in the chart below, the accessibility of the site plays a big role in selecting a repair method. Bringing in heavy equipment or a load of rock to a remote site can sometimes cause more damage than the gully itself. Whatever method you use, follow the guidelines carefully and be vigilant about checking the site and repairing any damage promptly during the first two or three winters.

SELECTING A HEADCUT REPAIR

Type of Headcut Repair	Gully Activity*	Flow Velocity	Common Reasons for Failure
Shaping and revegetation, herbaceous cover	low to moderate	slow (up to 2 feet per second) to medium (2–5 feet per second)	Poor germination rate due to late or early seeding; incorrect seed mixture or fertilizer application; mulch slippage; slope at too steep of an angle
Shaping and revegetation, willow sprigs	low to high	slow to medium	Sprigs planted upside down, too sparsely, not deep enough or too late; sprigs too small; insufficient water in dry season; slope too steep; animal damage
Shaping and revegetation, other trees and shrubs	low to moderate	slow	High flows tear out plants; insufficient water in dry season; slope too steep; animal damage
Shaping and rock riprap	low to high	slow to fast (over 5 feet per second)	Rock too small; no filter under rock; rock not tightly placed; slope too steep
Shaping, rock riprap and woody plants	low to extremely high	slow to medium	Insufficient water in dry season; slope too steep; animal damage; rock too small; no filter under rock; rock not tightly placed; if sprigs, too small or planted upside down, too sparsely, not deep enough or too late
Rock riprap only	low	slow	Rock too small; no filter under rock; rock not tightly placed; slope too steep
Willow only	low	slow	Sprigs planted upside down, too sparsely, not deep enough or too late; sprigs too small; insufficient water in dry season; slope too steep; animal damage
Diverting flow	Very low if no other measures are taken	slow	Diversion does not trap all water flowing into gully

* Low—Headcut is shallow (less than 3 feet deep) and does not grow noticeably during heavy rainfall. Banks are gently sloped and mostly covered with grass, tree roots or other vegetation.

Moderate—Headcut is shallow, but expands noticeably during winter storms. Banks are gently sloped and mostly covered with vegetation with occasional steep areas of raw, exposed soil.

High—Headcut is more than 3 feet deep and moves rapidly uphill during heavy rainfall. Banks are steep with little vegetation.

Shaping and Revegetation with Herbaceous Cover

Pulling back the headcut to an angle of repose and smoothing the soil surface distributes the runoff flowing into the gully over a wider area and reduces the energy given off as water falls a vertical distance. It is the difference between watering lettuce transplants full blast with a regular hose end and watering them with a sprinkler attachment.



Shaping a gully headcut

Once the headcut is shaped, the surface soil needs to be protected. In areas with good sun exposure, grass forms a strong, dense mat that withstands high flows. Seed mixtures that contain several kinds of annual and perennial grass, as well as nitrogen-fixing legumes, are recommended because they provide long-term protection and a backup in case one kind of seed doesn't perform well at the site. Native grasses are more difficult to find commercially, but they are often desirable for restoring relatively pristine areas. Your local Soil Conservation Service field office or seed dealer can help you find an appropriate grass mix.

Seed is usually sown between August 15 and October 1 in northern coastal California. In gullies, it is critical that seed be applied early enough to receive one or two light rainfalls in order to germinate and take root before the gully-washers come. The seed and a fertilizer containing sulfur, such as ammonium phosphate sulfate (16-20-0), should be applied evenly at the rate specified by the SCS technician or seed dealer. Seed application rates range from 5 to 500 pounds per acre; a common application rate for 16-20-0 fertilizer is 500 pounds per acre. Many seed dealers rent hand spreaders (sometimes called "belly-grinders") that can be set at the required rates. Otherwise, you can hand broadcast both the seed and fertilizer as uniformly as possible.

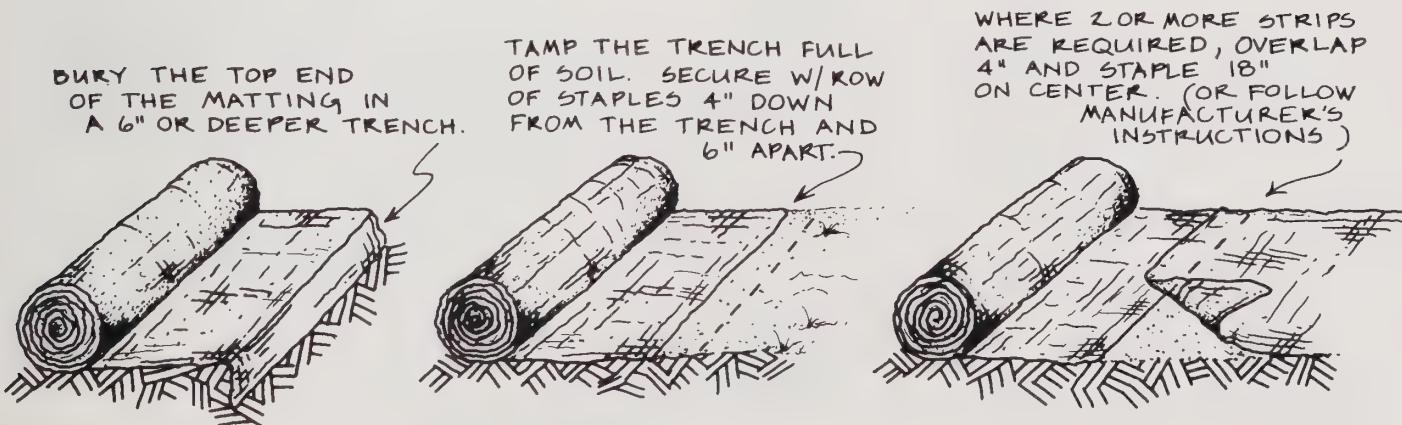
The seed and fertilizer should be lightly raked into the slope so they are buried with about 1/4 inch of soil. The surface should then be covered with a mulch, both to hold the seed on the slope and to protect it from hungry birds and small mammals. The type of mulch used depends on slope, wind, site accessibility and project budget. Clean straw, spread evenly at approximately 2 bales per 1000 square feet and fluffed to 3 to 4 inches thick, works well by itself on gentle slopes, but on headcuts it should be secured with a netting, such as jute or a light, sunlight-degradable polypropylene mesh applied with staples or wooden stakes as specified

by the manufacturer. Excelsior mat, which combines polypropylene netting with fine wood fiber, works excellently on headcuts.

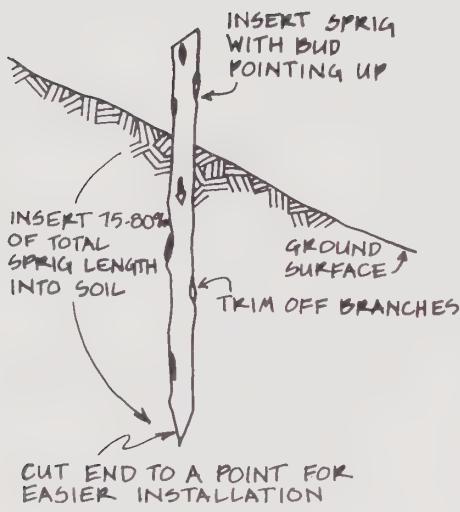
Shaping and Revegetation with Willow Sprigs

Willows, planted with grass seed or by themselves, are an effective and inexpensive way to armor active headcuts and gully banks, but most species of willow require soils that stay moist through the dry season. In fact, by absorbing and using water, they can help dry out an oozing headcut. Willows need a sunny site to thrive. Sprigs should be collected and planted when the willows are dormant. They should be at least 1/2 inch in diameter, 3 to 4 feet long and stripped of all branches and leaves. Fatter sprigs, 1 to 1½ inches in diameter, work best and should be used in the most actively eroding places. If the sprigs must be transported to the planting site or stored for a few days, keep them covered with wet burlap sacks.

Willows respond well to heavy pruning, so don't be too worried about collecting generously from a grove. Thin, however, instead of clearcut in order to leave cover for the resident fauna.



Erosion control mat



Willow sprig installation

Be sure to plant the willows right-side up. One almost foolproof method is to point the planting end of the sprig with an axe right after it is cut from the tree. The sprigs should be driven into the soil 75 to 80% of their total length at a slight downstream angle to lessen their resistance to the flow. In hard soils, holes can be prepared with a piece of rebar. A handle welded to the top makes the rebar much easier to pull back out. In softer soils, the sprigs can be driven in with a wooden mallet or a small sledgehammer.

The spacing of the sprigs depends upon the activity of the headcut. In more stable gullies with relatively small watersheds, the sprigs can be placed 2 feet apart. In large or rapidly eroding gullies, space the sprigs 1 foot to 18 inches apart.

Willows spread easily—usually an advantage; but in some cases when an open channel is needed to carry stormflows, this can be a nuisance. In such places, a less invasive plant should be used or a regular maintenance program implemented to keep the growth under control.

Cattle and deer find tender, young willow sprouts quite delectable. Be forewarned, and protect your plantings if you expect them to be exposed to heavy browsing.

Shaping and Revegetation with Other Trees and Shrubs

Rooted trees and shrubs can also be planted in headcuts and other gully points, but they are not recommended for active gullies until the headcut has been stabilized with a temporary method, such as an annual grass cover. Since trees and shrubs are best planted during the rainy season, they won't have a chance to grow strong root systems before stormflows; and unlike willows, you can't bury 75% of their length and expect them to live! Tips for planting container stock and recommended species are included in the appendix.

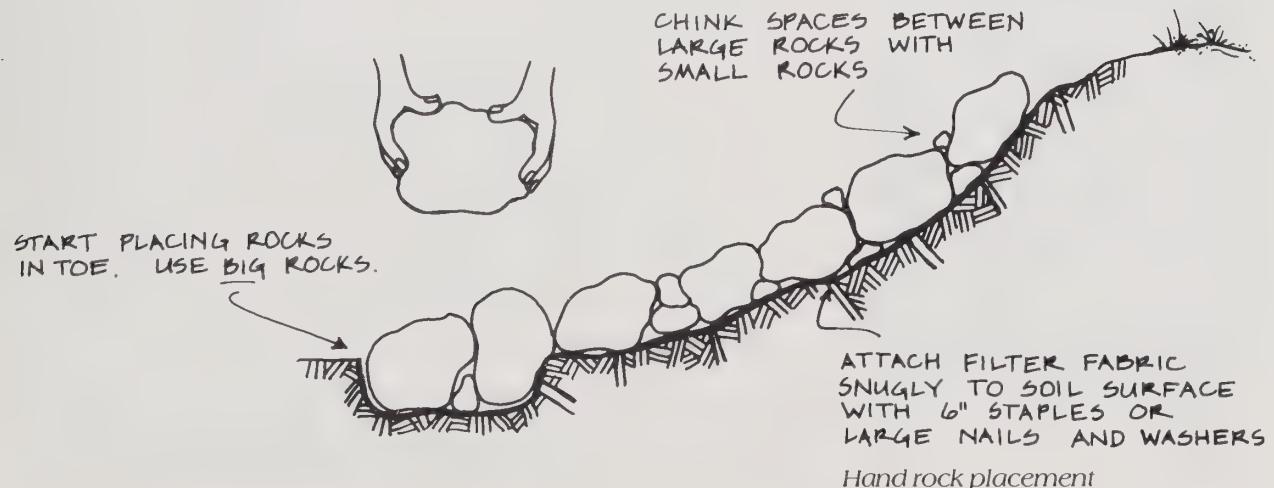
Shaping and Rock

Rock is commonly used to armor shaped headcuts and nickpoints. Unlike vegetation, rock forms an instant nonerodible surface; but it must be carefully sized and

installed to stay in place during stormflows. The two most common causes of failure are piping and rock movement. Piping occurs when water finds a cranny between the soil and the rock layer and proceeds to wash away the soil underlying the riprap. A layer of gravel or filter fabric below the rock allows water to percolate through without moving the soil. A thick layer of organic litter, such as pine needles and other leaves, can also be used effectively as a filter.

Many kinds of filter fabric are available. Again, your local SCS field office or building supply store can help you choose the right one. Some of the filter fabric characteristics to check include the following:

- *Photodegradability.* Some fabrics disintegrate in sunlight. Since the fabric is covered with rock for headcuts, this will matter only if you intend to use the same fabric for other work, such as lining redwood checkdams.
- *Woven versus nonwoven fabrics.* Woven, monofilament fabrics work well for most erosion control uses.
- *Permeability.* Fabrics vary greatly in opening size. Depending on the soil and fabric type, the openings may plug up and the filter will become ineffective.
- *Installation.* Some fabrics have a back and a front. Water flows through in only one direction, so correct installation is critical.



Filter fabric has the advantage over gravel of being easy to transport and install, but it inhibits volunteer vegetation from becoming established between the rocks. In several west Marin erosion-control projects, grass has germinated in the thin layer of soil collected on top of the fabric, and the roots have penetrated the filter, but no woody plants have been seen volunteering through fabric-lined rock. Although willow sprigs planted through holes cut in the fabric have done well, their continued success over a long period of time is not known. Generally, filter fabric is recommended for slopes steeper than 2:1 (2 feet horizontal run for a 1 foot vertical rise) and gravel for gentler slopes.

Big storms can wash away the most carefully installed rock, but you can substantially reduce the chances of failure by following these guidelines:

1. Slope the headcut back at a gentle angle. A 2:1 or gentler slope is best, 1:1 is minimal and should be used only on slopes less than 4 feet tall.
2. Use angular, not rounded, rock.
3. Lock large rocks tightly together with smaller ones. Placing rock is like putting together a jigsaw puzzle—you have to search through the pile to find the right rock for each spot. You should be able to walk on the rock-covered surface without wiggling individual rocks.
4. Use dense rock. Riprap should have a minimum specific gravity of 2.5, which means that a cubic foot of rock weighs 2.5 times a cubic foot of water.
5. Size the rock according to the flow velocity. The appendix includes a table for sizing rock. Even when you use the table, it's good also to look at neighboring drainages with similar flow velocities and see what size rock stays in place there. Bigger is always better.
6. Check the rock work frequently during the first two to three winters. If you see any cavities, rearrange the rocks securely, or pack them tightly with stones or flexible, leafy brush.

LIZA PRUNUSKE



Headcut armored with rock riprap and grass seed

Shaping, Rock Riprap and Woody Plants

Willow sprigs or other trees and shrubs planted between rocks add both wildlife value and stability to headcut repairs.

The sprigs should be driven into the headcut first and the rock placed around them. Gravel or an organic litter layer should be used under the rock instead of filter fabric.

Rock Riprap or Willow Only

In a pinch, both rock riprap and willow sprigs can be used without sloping the headcut, but not as effectively. With rough, vertical or near-vertical sides, it is much more difficult to form an impenetrable union between the rock face and the soil. Piping and mass rock movement are therefore far more likely to occur.

Diverting Flow

Diverting the water from a gully can be an effective but risky way to reduce headcutting. This method is best used when the gully has clearly been caused by channelled drainage, as in the case of a road culvert focusing the runoff from a wide area into a narrow channel. Because rain and groundwater will collect in the gully even if the major flow has been rerouted, the headcut will still require armoring, although it need not be as sturdy as without the diversion. Diversion alternatives include the following:

- **Redistributing the runoff over its original ground surface.** This usually involves using heavy equipment to reslope the land to approximate the natural contours. Chapter 5 describes methods of sloping unpaved roads to avoid forming gullies.
- **Redirecting the runoff to a different area.** Extreme care must be taken with this method because it can recreate the same problem in a new spot. It should be used only when no other options are available and then with some good advice. (Chapter 10 lists sources for professional help.) The runoff should be directed to a stable area, either a natural rock outcrop or an energy dissipator as described for road repairs in Chapter 5. Surface berms, subsurface drains and culverts are methods of moving runoff.

STABILIZING THE GRADIENT: CHECKDAMS

Once the headcuts are stopped, the next steps are to slow down the flow and to raise the level of the gully. Checkdams



Redwood board checkdam and rocked headcut

accomplish both of these tasks. All checkdams fall into two broad categories: porous and impermeable. Porous checkdams allow water to percolate slowly through the dam face. Sediment is deposited more slowly upstream than if the water was completely stopped, but such dams are more resistant to blowouts than impermeable dams. Materials used to construct porous checkdams include strawbales, woven willow branches, brush, loose rock, gabions and logs. Impermeable checkdams include redwood board, compacted earth, mortared rock and concrete structures.

As long as the basic guidelines are followed carefully, many other on-site or readily available materials can be used for constructing checkdams. Since the dams are in watercourses, avoid using toxic materials, such as creosoted railroad ties or pressure-treated peeler poles. Remember also that the dam will last only as long as the materials used to construct it, unless vegetation is either planted in the deposited soil or allowed to grow back naturally.

SELECTING A CHECKDAM TYPE

Type of Checkdam	Gully Activity*	Optimum Gully Size	Soil Particle Size	Durability	Special Site Conditions	Common Reasons for Failure
Strawbale	low	3–6 ft. wide, up to 3 ft. deep	fine to coarse	2–3 years	Use only in areas that can be seeded or where natural revegetation will occur quickly.	Bales not keyed into banks and bottom securely; animal damage; gully too active and requires more durable structure; no follow-up revegetation.
Woven Willow	low	up to 4 ft. wide, up to 3 ft. deep	coarse	indefinite	Use only in winter swales and where minor flooding is acceptable. Works best in gravelly soils with much organic matter such as leaves and twigs.	Sprigs planted upside-down, too sparsely, not deep enough or too late; insufficient water in dry season; animal damage.
Brush	low to moderate	up to 4 ft. wide, up to 3 ft. deep	coarse	2–3 years, indefinite if live willow stakes used		Brush not anchored securely to stakes; insufficient amount of brush; large poles used instead of smaller, leafy branches.

Loose Rock	low to high	up to 10 ft. wide, up to 10 ft. deep	fine to coarse if filter fabric used	indefinite	Rock on-site, or site accessible to dumptruck or loader.	Rock too small; not securely keyed into banks and bottom; spillway too small.
Gabion	low to high	One gabion width less 2 ft. key width, 3–10 ft. deep	fine to coarse if filter fabric used	20+ years	Rock on-site, or site accessible to dumptruck or loader.	Not securely keyed into banks and bottom; energy dissipator does not extend far enough downstream; spillway too small.
Log	low to moderate	up to 4 ft. wide, up to 3 ft. deep	coarse	5–20 years depending on type of wood	Works best in gravelly soils with much organic matter such as leaves and twigs.	Not securely keyed into banks and bottom; energy dissipator does not extend far enough downstream; gaps between logs too large; spillway to small.
Redwood Board	low to high	2–10 ft. wide, 2–5 ft. deep	fine to coarse if filter fabric used	20+ years depending on quality of redwood		Not securely keyed into banks and bottom; poor quality wood used; energy dissipator does not extend far enough downstream; active gully bank erosion; spillway too small.
Grouted Rock	moderate to high	3–10 ft. wide, 3–10 ft. deep	fine to coarse	50+ years		Not securely keyed into banks and bottom; air spaces left between rocks; spillway too small; energy dissipator does not extend far enough downstream.
Concrete	moderate to high	3–10 ft. wide, 3–10 ft. deep	fine to coarse	50+ years		Not securely keyed into banks and bottom; spillway too small; energy dissipator does not extend far enough downstream.
Compacted Earth	high	10–40 ft. wide, 10–30 ft. deep	fine to coarse	indefinite	Check with design engineer.	Insufficient soil compaction; spillway not protected with non-erodible armor such as rock or concrete; energy dissipator too light and/or does not extend far enough downstream.

* Low—Headcut is shallow (less than 3 feet deep) and does not grow noticeably during heavy rainfall. Banks are gently sloped and mostly covered with grass, tree roots or other vegetation.

Moderate—Headcut is shallow, but expands noticeably during winter storms. Banks are gently sloped and mostly covered with vegetation with occasional steep areas of raw, exposed soil.

High—Headcut is more than 3 feet deep and moves rapidly uphill during heavy rainfall. Banks are steep with little vegetation.

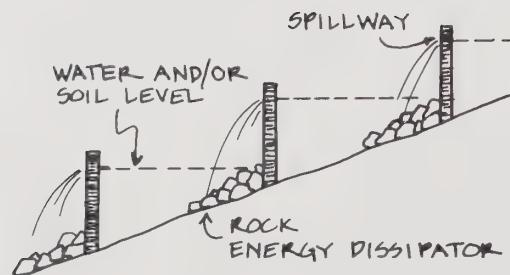
Guidelines for Checkdam Construction

1. A series of short dams is usually more effective than fewer tall dams. If one dam fails, the entire gully repair will not be threatened. Also, since taller dams work harder, holding back a greater volume of water and soil, small flaws in construction are more likely to cause major failures. Short dams can be raised over a period of years, if necessary, to heal a deep gully. No dam should have an effective height of more than three feet without being designed by an engineer.
2. Use a hand lever or clinometer to space the checkdams so that the *toe* of one is level with or slightly below the *spillway* of the downstream dam (see illustration). Otherwise, the gully will continue to deepen and undermine the upper checkdam.
3. All impermeable dams and most porous dams require a spillway to prevent cutting of the gully banks. The spillway may be a well-defined notch or, in the case of a loose rock dam, simply a sloped depression. Trapezoidal notches are recommended because they are less likely to trap debris than rectangular openings.

The spillway should be large enough to accommodate normal stormflows. Gullies are usually in natural drainages. If they are filled completely, runoff will overflow and may cause gullying somewhere else. One method of sizing spillways is to provide an equivalent opening to the culvert diameter needed to carry the same flow. (See the appendix, or consult your SCS field office for advice.) The following chart shows another method based on the acreage of the watershed draining into the gully.

Be careful to aim the spillway at the bottom of the gully, not the sides, even if this requires that the spillway be off-center.

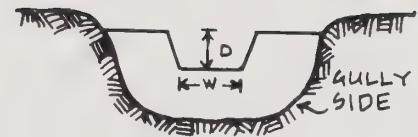
4. Always provide a nonerodible energy dissipator (or apron) for the checkdam overflow. Rock or securely anchored brush are two of the most commonly used materials. During high flows, the aprons are subject to tremendous force. Aprons that are too short or not strong enough are frequent causes of checkdam



Checkdam placement

SPILLWAY SIZE FOR CHECKDAMS

Area of Gully Watershed	D if W = 12 inches	D if W = 18 inches	D if W = 24 inches	D if W = 36 inches
1 acre	6 inches	4 inches	3 inches	3 inches
2 acres	9 inches	7 inches	5 inches	4 inches
3 acres	12 inches	8 inches	7 inches	5 inches
4 acres	—	10 inches	8 inches	6 inches
5 acres	—	12 inches	10 inches	7 inches



failure. A row of rebar or willow stakes driven in 6 inches to 1 foot apart at the toe of a rock energy dissipator can help hold it during stormflows. A piece of filter fabric or a layer of leaf litter should be placed under the rock to prevent the soil from washing away. The apron should extend across the entire width of the gully.

5. The top of the checkdam must be level. Even with a large spillway, stormflows sometimes overtop the dam. If the water is focused on one bank, you can almost count on bidding your dam adieu.

6. **Key** all checkdams securely into the gully banks and bottom. Key depth varies according to the size and type of dam and is discussed further in the following descriptions of checkdams. The soil around the keys should be firmly tamped in 2 inch lifts. Only soil, no rocks, should be used. If the soil is very dry or very wet, it won't compact well.

7. Construct checkdams perpendicular to the flow. This is easy in a straight gully, but a little tricky in a more typical, sinuous one.

POROUS CHECKDAMS

Strawbales

Strawbales are an inexpensive and easy-to-install form of checkdam for use in mild, shallow gullies. They perform best in gullies with relatively stable sides and some existing grass cover. Since the bales deteriorate in two to three years, it is essential that vegetation be well established on the deposited sediment within that time. Bales should be keyed into the bank as shown and secured with two pieces of rebar per bale. Multiple bales can be used in a row across the gully floor.

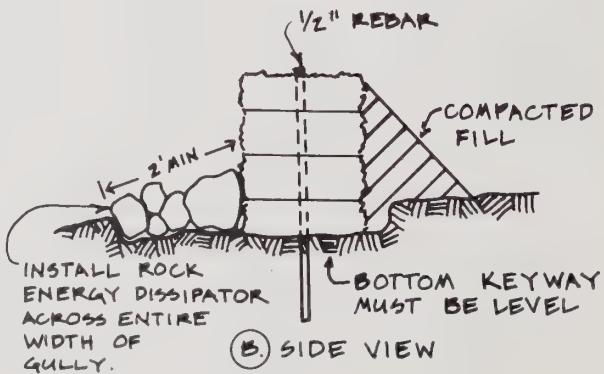
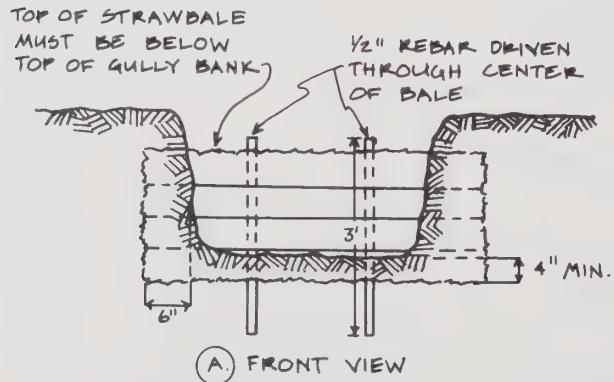
Generally, single strawbale checkdams are constructed without spillways. If you find runoff overflowing the gully channel during a rainstorm and causing damage elsewhere, you can cut an emergency spillway with a pick or a chainsaw, but be very careful of the wire and the rebar! Multiple strawbale dams can be arranged so that the center is lower than the sides.

If cattle have access to strawbale checkdams, they may eat the checkdams down to two lone pieces of rebar. Wrapping the bales in chicken wire before installing them usually discourages such voracity.

Woven Willow Checkdams

In gullies where the soil does not completely dry out in summer, living checkdams can be constructed out of willow branches. As stated above, be careful not to obstruct completely a channel needed for storm runoff. Willow

Strawbale checkdam



checkdams are best used either in conjunction with diversion of the gully flow (see discussion under headcuts) or in highly erodible soils where the gully has cut a channel much deeper than that needed for even severe stormflows. The great advantage of woven willow checkdams is that they provide both structural stabilization and revegetation all in one step.

The willow branches should be cut and cared for as described for willow sprigs. The upright poles should be 3 inches or greater in diameter, depending on the height of the structure. The taller the dam, the stronger the poles need to be. The poles should be stripped of all side branches and driven into the ground (right-side up). Slender branches, 1/2 inch or smaller in diameter, with side branches and leaves left attached, are then woven through the poles and tucked into keys excavated into the gully sides and bottom. Soil must be compacted firmly around the keys as it is with a strawbale or wood dam.

Because they will never form a solid wall, but merely a thicket of dense growth that will slow down flow, woven willow dams do not require a downstream energy dissipator unless debris gets trapped behind and plugs them. As with all erosion control work, keep a close eye on the dam during the winter, and if you have any doubts, add an apron.

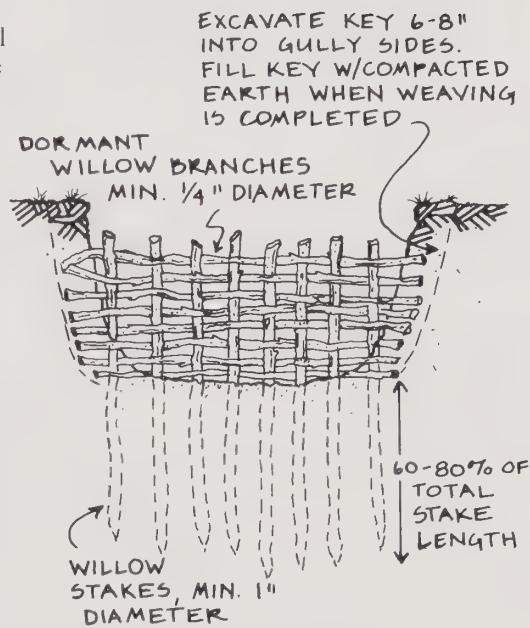
Brush Checkdams

Brush checkdams are especially useful for hard-to-reach, small gullies with a plentiful source of woody branches nearby. Brush checkdams require wooden poles, preferably willow, 3/4 inch rebar or steel t-posts (triangular fence posts) driven into the gully bottom as described for woven willow checkdams. A 6 inch layer of organic litter is laid on the gully floor both upstream and downstream of the posts, and then green branches are stacked on top of the litter, butt end upstream, and secured to the posts with strong, galvanized wire. Longer branches should be placed on the bottom, extending further downstream, to form the energy dissipator.

Construction techniques for additional types of brush checkdams, including some for larger gullies, are well described in References 1, 2, 7 and 8 listed in Chapter 10.

Loose Rock Checkdams

Loose rock dams are one of the most adaptable types of checkdam. They can be used effectively in all but the largest



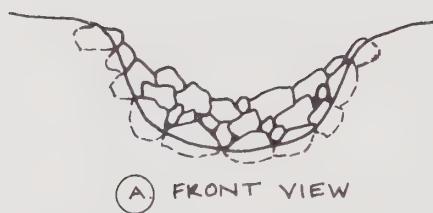
Woven willow checkdam

gullies, if the rock is sized correctly and carefully installed and the effective height of the dam does not exceed 4 feet. The guidelines for sizing and basic placement are the same as described for rocking headcuts.

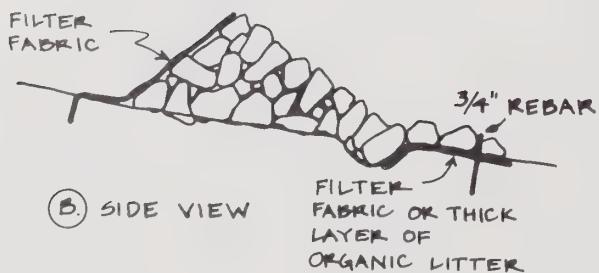
Loose rock checkdams can be constructed by hand or with heavy equipment. Like all checkdams, they must be keyed securely into the sides and bottom of the gully. In gravelly soils or areas where large amounts of organic litter such as leaves, moss and small branches are carried in the runoff, you may get by without lining the upstream face of the dam with filter fabric. The gravel and litter tend to lodge in the interstices between the rocks and block fine soil particles. However, even in such instances, filter fabric will help keep your checkdams from washing away and should always be used when the effective height of the dam is more than 2 feet.

Installation of the filter fabric is critical to the success of loose rock checkdams and others where it is specified. The fabric must be inserted into the sides and below the soil surface at the gully bottom, or water will flow around it and defeat its purpose.

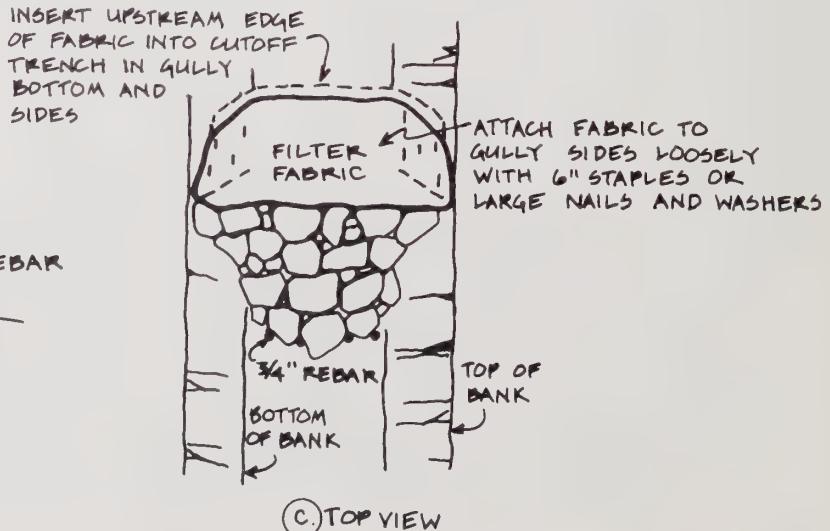
In dams with an effective height of 3 feet or less, a row of 3/4 inch rebar placed between the crest of the dam and the downstream end of the apron helps hold the rock in place during stormflows. It is much easier to drive in the rebar before placing the rock, but on small dams, it can be inserted later if



(A) FRONT VIEW



(B) SIDE VIEW



Loose rock checkdam

the dam integrity is suspect. Space the pieces of rebar 8 to 12 inches apart and pound them in flush with the rock.

Gabion Checkdams

Gabions are rectangular wire baskets which are filled in place with rock. In essence, they make one big rock out of many smaller ones. Gabions come in various sizes and are useful where large rock is not available. Manufacturer's instructions should be followed when assembling and installing them. Gabions should also be backed with filter fabric applied as described for loose rock checkdams. The trench in which the gabions sit should be shaped to create the spillway. Even a single gabion dam can be molded so the ends curve upward.

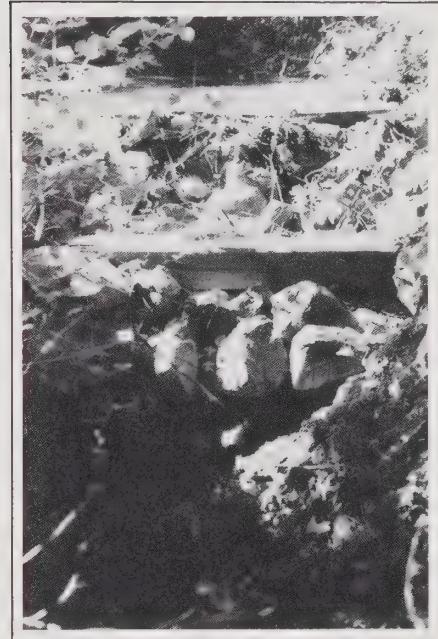
The most frequent point of failure in multiple gabion dams is the wire holding them together. Once the wire breaks, an errant gabion can pull out all those attached to it, unlike loose rock dams, which can remain largely intact even when part of the structure washes away.

The gabion concept of holding small rocks in place can be employed by pinning chainlink fence over small loose rock checkdams. Pieces of rebar bent into hooks work well to secure the fence.

Log Checkdams

Checkdams made from on-site logs are suitable for small gullies with a width of 3 feet or less. Unless backed with filter fabric, log dams should be used only where the runoff is rich in organic litter. Any available wood can be used, but remember that some species, such as California bay and alder, rot quickly.

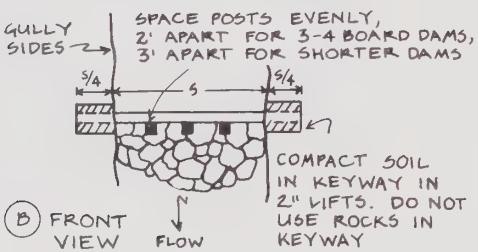
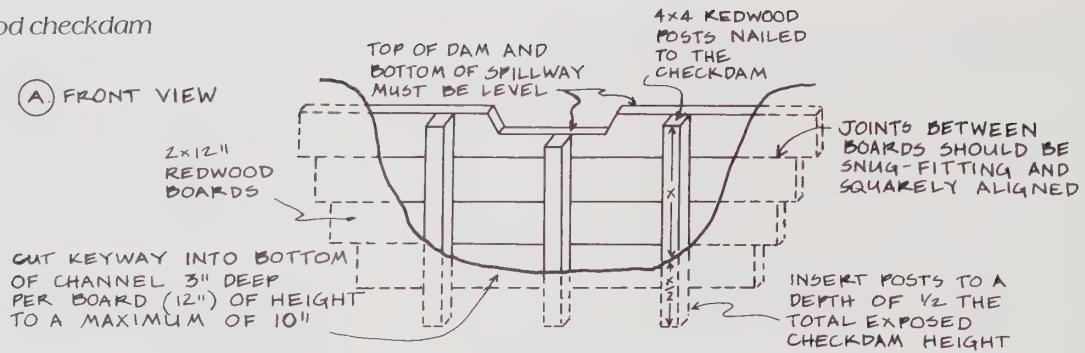
The closer the logs fit together, the more effective the dam will be in trapping sediment. The logs should be inserted 1 foot deep into the banks and 6 inches into the gully bottom. If possible, a spillway should be cut into the top log, but always leave at least 4 inches of the log diameter intact or the log may break under force. The apron can be either rock over a layer of litter or filter fabric, or a thick layer of securely anchored leafy brush. If filter fabric is not used, the upstream toe of the dam should be sealed with a 6-inch layer of organic litter held in place with rock. The upstream rocks need not be as large as those forming the apron, since the dam itself will prevent them from rolling downstream.



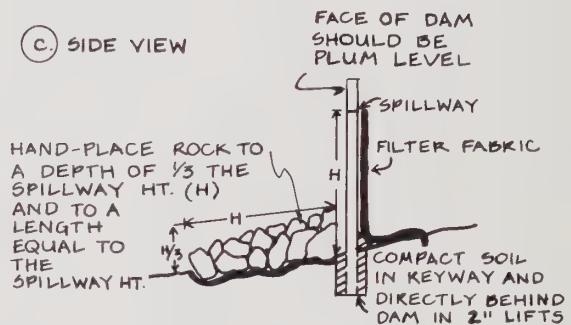
Split redwood log checkdams

Redwood checkdam

(A) FRONT VIEW



(C) SIDE VIEW



INSERT FABRIC 6" MIN. INTO GULLY BOTTOM AND SIDES. NAIL TO FACE OF DAM. ATTACH TO BANKS WITH 6" STAPLES OR LARGE NAILS AND WASHERS.



IMPERVIOUS CHECKDAMS

Redwood Board Checkdams

Redwood board dams are suitable for spans up to 10 feet wide with an effective height of up to 3 feet. Constructed carefully, they are durable and capable of quickly raising gully levels, often filling after one rainstorm. The redwood used should be heartwood and free of large knots.

Thorough compaction along the bottom and sides of the dam is absolutely critical, as with all impervious dams, to prevent piping. Upstream filter fabric, installed as shown, also helps. Nail the fabric loosely to the face of the dam; if it is too taut, it breaks under the weight of the trapped water and sediment.

Grouted Rock Checkdams

Like gabions, grout unifies small rocks into a larger mass. It also creates an impermeable structure that will fill quickly if constructed well and fail spectacularly if not. If you choose this technique, heed a word of advice: start small. Compacting soil around the keyways can be very difficult because of the irregular surface of the structure. One west-Marin rancher successfully uses a high-pressure water hose to pack soil in and around grouted rock dams.

The mix should be 1 part mortar to 3 to 4 parts clean, sharp sand. The depth of the keyways should equal half the total height of the dam and be filled with mortared rock. The surface rock should be left well exposed, particularly in the apron, to dissipate the energy of the water as it flows over the dam.

Concrete Checkdams

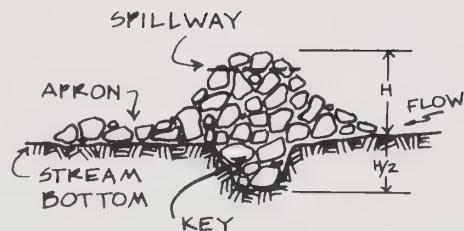
Reinforced concrete checkdams are especially useful in gullies that have cut down to bedrock. They are durable and can be tailored to fit any shaped channel. As with grouted rock dams, the depth of the keyway should equal half the total height of the dam. Reinforce the concrete with 1/2 inch rebar placed 12 inches on center or 6 x 6 inch #10 wire mesh. Remember to install an apron of concrete and/or rock. Dams of more than 3 feet in effective height and 10 feet in width should be designed by an engineer.

Preformed concrete checkdams are now available in some areas. Your SCS field office can tell you where to find them locally. The manufacturer's installation instructions should be followed.

Compacted Earth Checkdams

Compacted earth dams with concrete-lined spillways are used in huge gullies, either singly or in a series. Their effective height ranges from 10 to 20 feet, and they must be engineered. Soil for the dams is usually collected from the banks above the dam site; in the process, the banks are smoothed to a more stable angle. In rangelands, these dams can provide water for livestock and wildlife, as well as slow erosion.

After construction, the downstream dam face should be seeded with a grass mixture and covered with mulch as discussed for headcuts.



Concrete or grouted rock checkdam

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Compacted earth checkdam with concrete spillway

STABILIZING GULLY BANKS

The primary objective of stabilizing gully banks is to establish vegetation. In extremely active gullies, this may require sloping the banks back to an angle of repose so that the soil stays still long enough for something to catch hold. Smoothing the gully surface also inhibits the development of side channels. Small gullies can be shaped with hand tools; larger ones usually require tractors.

Riprap placed along the toe of the gully banks will prevent undercutting, but will not slow down erosion occurring from surface runoff spilling over the top edge of the banks. Riprap should be installed as specified for headcuts to a height above the level of the expected winter stormflows.

Banks can be planted with a herbaceous seed mix, willow sprigs or other woody plants using the techniques described for headcut repair. As with any type of revegetation, large animals need to be excluded at least until the plants are well established.

LIZA PRUNUSKE





4 Small Landslides

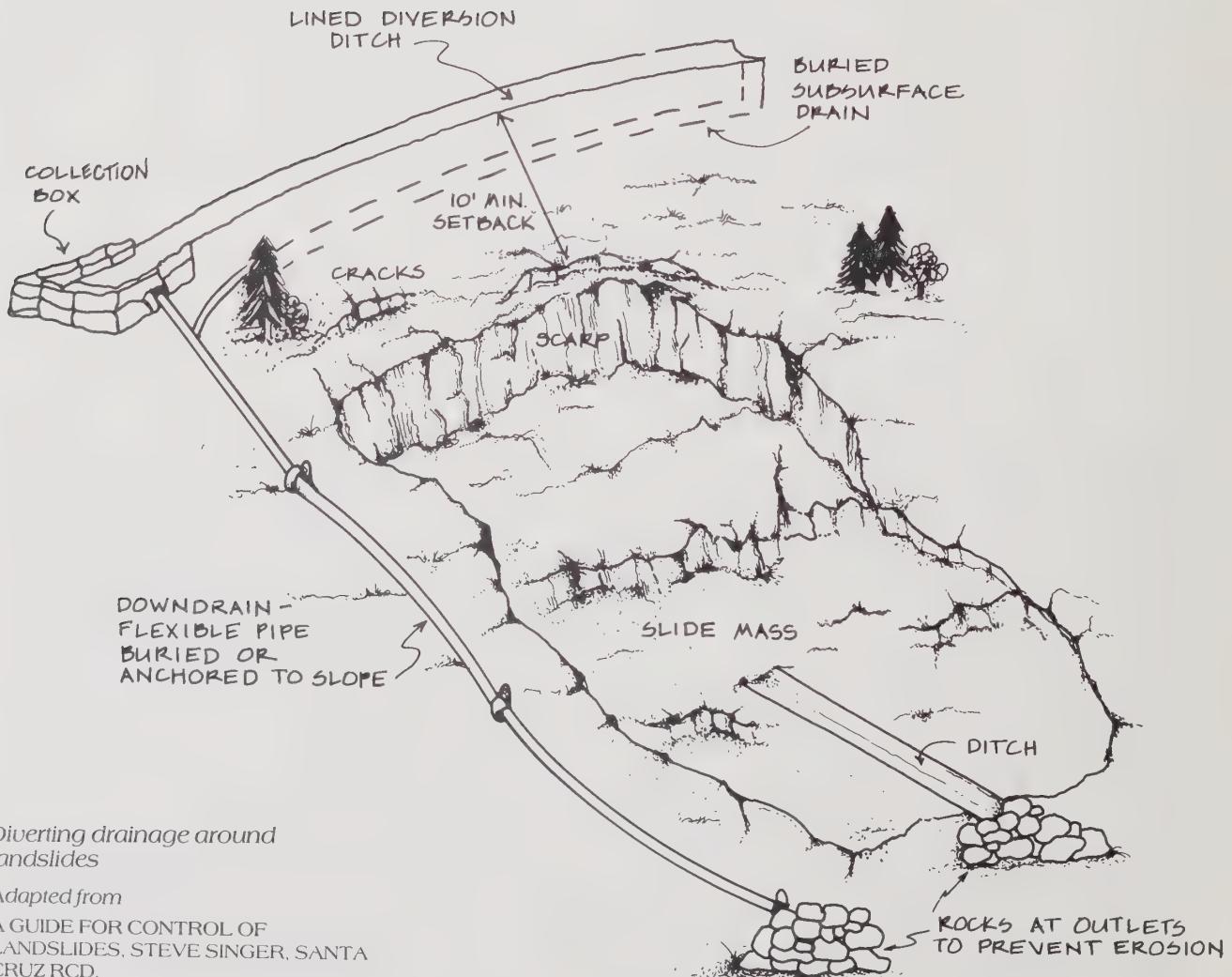
Although mass earth movements are notoriously difficult to predict or repair, there are ways to help prevent them or at least not to make them worse. No construction should occur on known landslides. If you have any doubts, contact your local planning department, a registered geologist or the slide references listed in Chapter 10. Existing dirt roads that are cut into landslides should be reshaped to the original contour, seeded, and abandoned, or at least outsloped. (See Chapter 5 on road erosion.) Runoff should never be channeled to a known slide area, and the existing vegetation should be left undisturbed.

In this section, we will address only small slides, those less than 2 feet deep that don't endanger any property or human lives. Before tackling anything more severe, you should seek help from a registered geologist.

Small slides often occur in droves after unusually severe storms and often revegetate by themselves within a year. If they are recovering slowly, they can be seeded with the same techniques used for headcuts. Since they are usually on extremely steep slopes, the mulch needs to be secured with some type of netting. The planting of trees or shrubs is recommended only if the slide is wet throughout the year or easily accessible for watering several times during the summer. Vegetation will not necessarily stop the earth movement—often the slides are much deeper than the root mass—but it will at least protect the surface from erosion and help take up excess water through evapotranspiration.

Subsurface drains above small slides will also reduce the amount of water flowing through the slide area. The pipe should be installed as shown at or below a clay or bedrock layer, if present, and at least 4 feet below the surface. If you

still can't find a distinctive change after 4 feet, the slide is too deep for a simple drain and you probably need some professional help. Reference 13 describes how to identify and control various kinds of landslides.



Diverting drainage around landslides

Adapted from

A GUIDE FOR CONTROL OF LANDSLIDES, STEVE SINGER, SANTA CRUZ RCD.



Roadways

Unsurfaced roads, driveways and even horse trails and footpaths contribute sediment directly, as well as cause and accelerate other erosion problems. The prime reason they are such troublemakers is that they collect and channel runoff. In building a new roadway, most of the typical problems can be avoided. Reference 17 is an excellent handbook for designing, constructing and maintaining safe and nondestructive small roads. However, in many areas of northern coastal California, the unpaved roads were built many years ago, often for short-term logging ventures, and have been plaguing watersheds ever since.

The following process can help get an eroding unsurfaced road in shape, as well as provide guidance for avoiding the same mistakes when constructing new roadways.

1. **Evaluate the surface drainage.** Most road erosion and related problems, such as gullies and landslides, are due to the way runoff reacts to the road surface. Through grading, the road drainage can be modified to reduce or eliminate such problems. The objective is to have the runoff travel as short a distance as possible before safely crossing the road and leaving at a well protected, non-erodible point. The longer the water travels, the faster it moves and the more erosive it becomes.

One road can incorporate several kinds of drainage to achieve this objective. There are four basic types:

- **Inboard ditch.** The road is graded into the slope. Water from the road and the hillside above it collects in a ditch and either runs the entire length of the hill or exits through culverts or waterbars. When properly done, the advantage of this method is that runoff is carefully controlled and can



OUTSLOPE



INBOARD
DITCH



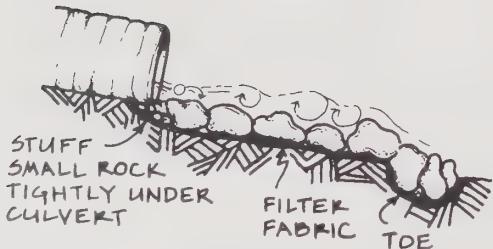
CROWN

Types of surface road drainage

Adapted from
ROAD BUILDING GUIDE FOR
SMALL PRIVATE ROADS,
MENDOCINO COUNTY RCD.



(A) TOP VIEW



(B) SIDE VIEW

Rock energy dissipator

be channelled to well-protected areas. Frequently, however, the runoff cuts deep gashes into the side of the slope, often destabilizing slides, and exits out gullies.

- **Crown.** The road surface is sloped gently towards both sides. This is usually used only on high-quality roads, often in conjunction with large cut and fill slopes. It is relatively uncommon on lightly used roads. Ditches and culverts carry runoff to either side, depending on slope.
- **Outslope.** The road is graded with the slope at a gentle angle. Culverts and ditches are not necessary, except where streams cross the road, because runoff sheets evenly from the road surface. Outsloping is the least destructive method to the natural drainage patterns. However, it should be avoided where the road surface is composed of fine, highly erodible soil, or on well-used curves where there is a danger of a vehicle sliding off the road.
- **Middle of the road.** Some old roads were constructed straight down the middle of a creek. The only safe way to get water off them is to direct it into lined ditches on one or both sides of the road. Ditches can be lined with a short and sturdy grass species, rock, concrete or *Gunnite*. In some cases, the only way to prevent serious erosion on such roads is to abandon and revegetate them, and build a better road elsewhere.

Herbaceous vegetation also helps protect road surfaces and slow runoff. On seldom-used roads, a grass-seed mixture can be sown directly on the roadbed to protect it during the winter season. Existing low plants should not be graded from roads unless they pose a fire hazard or dangerously limit visibility.

2. **Transport channelled water safely across the roadway.** Whenever there are ditches, or where streams and winter swales cross an unsurfaced road, look for erosion problems. Even a slight washout or rilled area that has to be regraded every year can contribute tens of tons of sediment to the nearest stream over a few years. One way to get a handle on how much soil has washed away from a seemingly stable road surface is to lay a flat stick or board across the road. Assuming that the road was once graded to a relatively flat surface, the ground between the stick and the current surface has been lost.

All types of cross-drainage except outsloping require that the water leave the road at a protected outlet. Rock energy dissipators are the most common form of protection. As shown, the rock should be placed over a filter fabric blanket. As with all rock used for erosion control, it should be angular and large enough to withstand heavy flows.

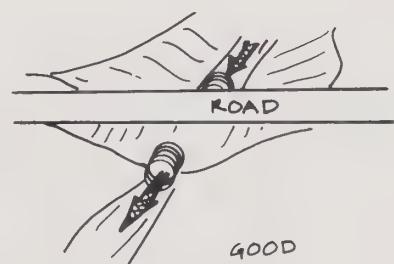
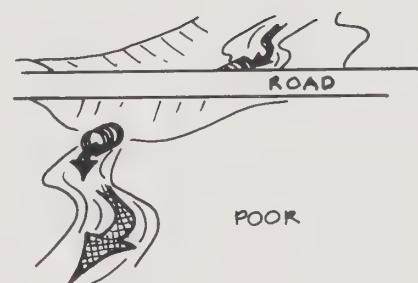
The method employed to transport flow across the road depends on how much use the road receives, the volume of flow, whether the road is regularly maintained and, of course, your budget. The last item can be deceptive, since more sophisticated methods, such as paved fords, often quickly make up for the high price of installation in reduced long-term maintenance costs. All methods must be sized to handle the desired stormflows. Here are four possible choices:

- **Culverts.** Culverts can be made of steel, plastic, concrete or redwood. Open-top culverts are flush with the road surface; enclosed culverts are buried beneath the surface. Specifications for spacing and installing culverts are given in Reference 17, but we will emphasize several critical guidelines here.

Culverts carrying stream flow should follow the natural alignment and exit flush with the downstream channel. Flow should be carried over fill slopes or unstable areas in downspouts or surfaced channels. Culverts should be sloped downward to prevent sediment from accumulating inside; a minimum of 6% is the recommended gradient for self-cleaning.

One of the most common causes of road washouts is plugged culvert inlets. They should be cleaned before the rainy season and checked during storms, often a time-consuming task since unsurfaced roads should not be driven on when they are wet. If a culvert plugs after every major storm, consider using another method and/or addressing the upstream source of debris. Trash racks or perforated risers can also help keep the culvert open, but they are certainly not maintenance-free.

- **Fords.** Fords are recommended for shallow stream crossings with debris problems or where winter access is difficult. They should be paved with reinforced concrete or rock to prevent erosion of the road surface. Fords should be designed for specific sites with help from the SCS or a professional engineer.

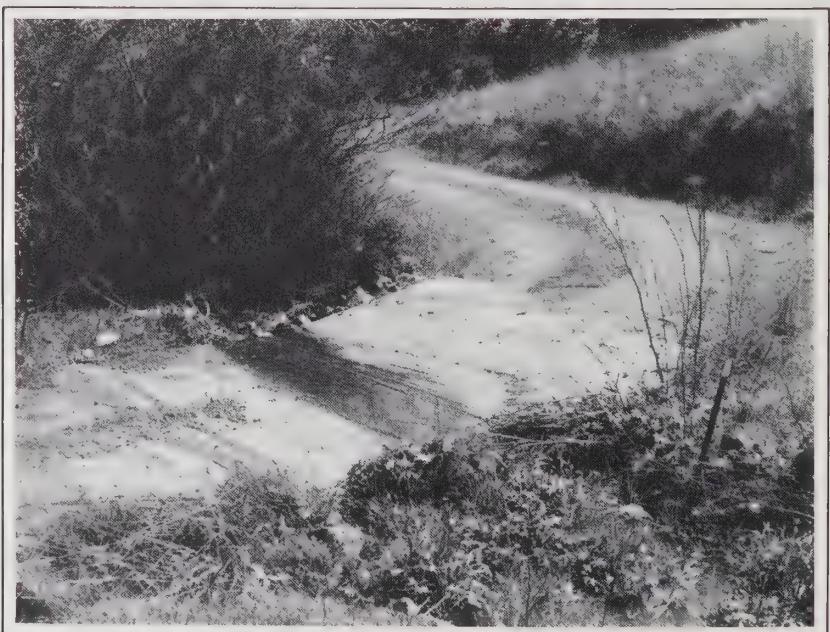


Culvert alignment

Adapted from
ROAD BUILDING GUIDE FOR
SMALL PRIVATE ROADS.
MENDOCINO COUNTY RCD.

- **Rolling Dips.** Rolling dips are essentially unpaved, miniature fords used for very small, seasonal tributaries. They should not be used on highly erodible road surfaces. Like fords, they have the advantage of requiring minimal maintenance to remain effective.
- **Waterbars.** Waterbars are a temporary means of breaking surface flow over sloped sections of road. In a pinch, they can be constructed with hand tools and are extremely effective at preventing rilling. They consist of a shallow ditch and rounded berm placed diagonally across the road surface. Often they must be reconstructed every year because they either wear down during the summer or are so annoying to those who regularly use the road that they are graded out in spring.

Waterbars can be made more palatable by increasing the width and thereby reducing the slope of both the ditch and the berm. Installing a series will reduce the flow volume and hence the cutting action in each waterbar. Care should be taken, however, not to place them so closely together on steep slopes that vehicles get stuck



Concrete ford

PAUL SHEFFER

halfway up the hill. A rule of thumb is to divide 1000 by the road grade to get the spacing between waterbars in feet. For example, if you have a 5% grade, you will need a waterbar approximately every 200 feet.

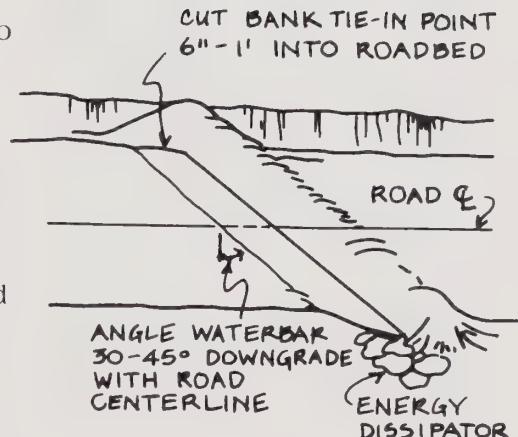
Waterbars can be reinforced with logs, gravel or soil cement.

3. Consider surfacing perennial wet spots. Driving over seep sites that remain wet well into the dry season often causes tremendous disturbance of the roadbed and subsequent erosion in winter. Such areas should be protected with a gravel road base placed over a layer of filter fabric to prevent the rock from mixing with the mud. Underground drains may also be needed to remove the water from the roadbed.

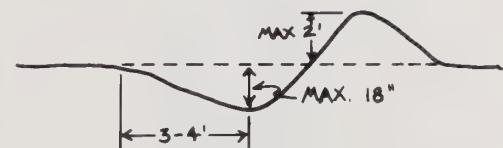
4. Undertake a regular maintenance program. Many road erosion problems can be nipped in the bud if the road is well maintained. A good dry-season maintenance program should include replacing energy dissipators that have washed away, cleaning culverts, replacing inadequate culverts with larger ones or another type of cross-drainage, adding additional cross-drainage if necessary, smoothing rills to prevent them from growing into gullies, modifying the surface drainage as needed and, in early fall, seeding the roadbed or adjoining areas of exposed soil.

In winter, energy dissipators should be inspected and reinforced if necessary, culverts and ditches kept clean, and rill erosion checked by constructing waterbars. Winter is also the best time to note where changes in surface or cross-drainage are needed.

As the major causes of road erosion are repaired, maintenance will become easier and our streams cleaner.



(A) TOP VIEW



(B) CROSS SECTION

Waterbars

Adapted from
ROAD BUILDING GUIDE FOR
SMALL PRIVATE ROADS,
MENDOCINO COUNTY RCD.



6 Streambanks

Streams are dynamic. They are constantly adjusting to weather patterns and changes in the watershed by modifying their channel shape through erosion. Chronic, severe streambank erosion usually indicates a major imbalance within the entire watershed. Treating the symptoms may save one section of streambank, but it will not solve the problem.

Sometimes short-term measures are the only viable solution, especially in urban watersheds, where paved roads, roofs and parking lots are considered an essential part of our lives. However, in rural watersheds, evaluating the entire watershed and attempting to reduce sediment sources and runoff rates in combination with repairing individual erosion sites may have more satisfactory long-term results. This requires skilled help from hydrologists, botanists, geologists and others. If you want to explore this approach, contact the SCS and other state, federal and local resource agencies (see Chapter 10) for assistance in getting started.

In this handbook, we will present only general descriptions of streambank erosion types and repair alternatives. Most streambank erosion sites, particularly where roads or structures are threatened, require engineered designs not only to increase the probability of an effective repair but also to prevent downstream damage caused by the repair. Mine sites, those that are not immediate emergencies and are less than 3 feet high and 10 feet long, can be addressed without engineering by using the same techniques recommended for repairing headcuts. Seeding and mulch, willow sprigs or other plants can also be installed without endangering downstream property.

Most streambank erosion can be classified into four types:



1. OUTSIDE CURVE

Sediment in a streambed is deposited where the gradient flattens out or where rocks, roots or some other mass slows the flow. In a typical scenario, the main line of flow, called the thalweg, moves to one side of the sediment buildup and cuts into the bank. As more sediment is added from upstream erosion, the flow further erodes the bank, which in turn adds even more sediment.

The on-site solutions to outside meander erosion are to armor the bank, making it nonerodible, to deflect the flow or to straighten the curve. All can have serious side effects. As water cuts the outside bank, it expends energy. If it can't cut there, it may cut somewhere else—either on a downstream bank, or in the case of channel straightening, in the bottom of the channel causing widespread bank failure.

Armoring the Bank

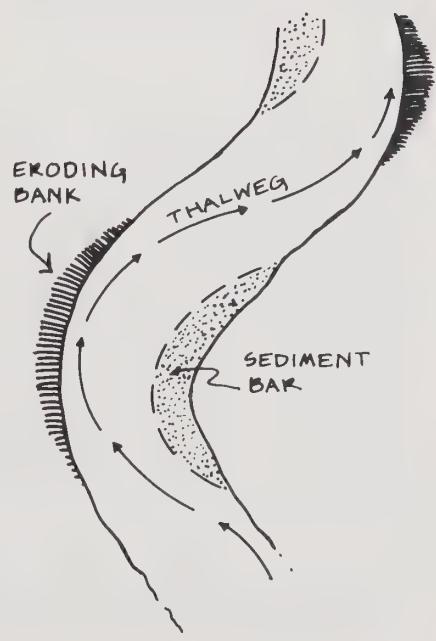
There are many types of bank armoring, some purely structural, some using only vegetation and some combining both elements. All armoring must be keyed securely into both the upstream and downstream banks to prevent eddy action from cutting behind the armor. Here is a summary of some of the more common types. Specifications for all of these methods are available through the SCS.

Rock Riprap

The rock is applied the same way as described for headcuts, including installing a filter. Instream excavation is necessary to key the rock into the bottom of the channel. Engineered designs usually require that the bank be laid back at a minimum 2:1 slope. Where homes or yards abut the creek, this is often not practical and another repair technique must be used. Vegetation can be planted between the rock.

Gabions

Gabions can be stacked more steeply than rock, but they also require instream toe excavation. Vegetation can become established in the gabions but not as easily as in loose rock.



Outside curve streambank erosion



Wood and concrete retaining wall

Retaining Walls

These are engineered walls usually made of reinforced concrete, redwood or various brands of interlocking, preformed concrete blocks. These walls are vertical and useful when space is scarce. They must be keyed into the channel bottom and tied into the bank with deadmen anchors or soil anchors. Plants cannot grow through solid retaining walls, although if they extend only partway up the bank, vegetation growing on top can still provide some shade and cover for instream wildlife.

Post and Wire

Posts and wire fencing can be used in a number of different designs to protect banks. Major instream excavation is not needed, because posts or pipe can be driven into the stream bottom. The fencing is applied vertically behind the posts, and then the structure is backfilled with cobble. Plants root readily at the base and eventually throughout the wall, as the crevices fill with soil.

Log or Concrete Crib Walls

Major instream excavation is also not needed for crib walls, but extensive bank excavation is frequently required to set dead men anchors. Crib walls need a slight setback and can be attractively interplanted with shrubs and vines.

Herbaceous Vegetation Alone

In small channels with existing grassy cover, bank failures can be sloped, seeded and mulched. Care must be taken to secure rigorously any mulch in stream courses. Often manufacturers have more stringent specifications for streambank application than for upslope stabilization.

Woody Vegetation Alone

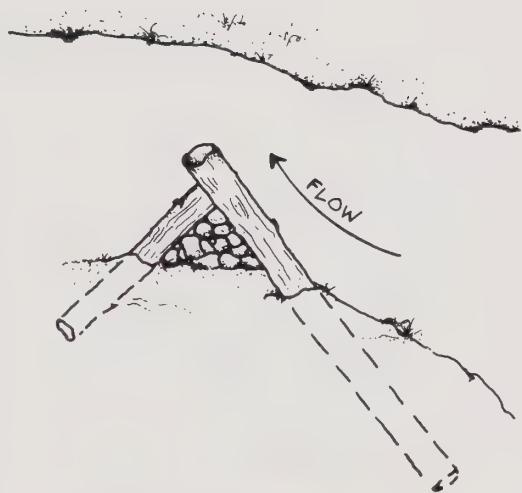
Except where the runoff velocity and volume have been so accelerated that roots alone simply cannot hang on to the banks, woody vegetation is the ultimate streambank armor. Where bank erosion is severe, with sharp, vertical cuts, the slope will usually require structural stabilization before vegetation can be successfully established. However, where the eroding banks have a more moderate slope, or at remote sites, shrubs and trees can be planted by themselves. Willows sprigs are inexpensive and can be

driven securely into the bank, but other plants can also be used if secured to stakes. Expect some loss from stormflows, so plant thickly, particularly in the most actively eroding areas.

Deflecting the Flow

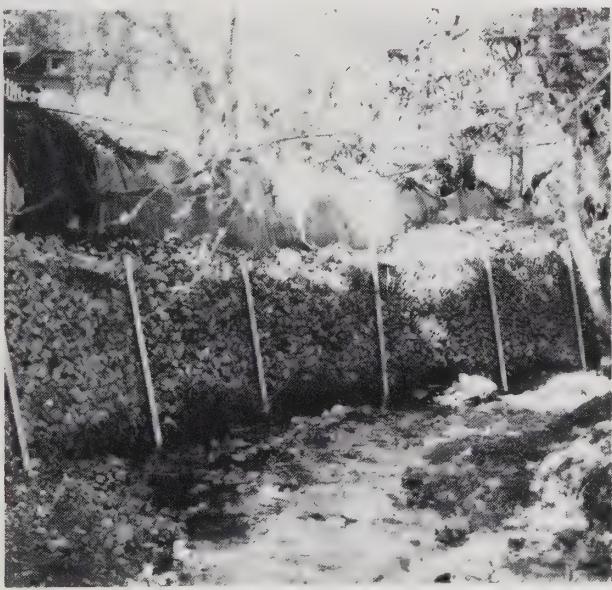
Deflectors are artificial obstacles attached to one bank, extending at an angle into the channel. They steer flow away from severe bank erosion, without drastically changing the flow pattern. At best, they buy time for the eroding sites, allowing vegetation to become established and secure the bank. At worst, they can cause additional erosion by aiming flow at unprotected banks.

Deflectors can be constructed of logs, rock or gabions. They should be securely tied into the bank and reinforced downstream as shown to prevent eddy erosion. The trick in getting deflectors to work the way you want is to extend them at the proper angle and far enough into the flow to deflect, but



Log wing deflector

PAUL SHEFFER



Steel pipe and wire revetment

RENÉE PASQUINELLI



Outside curve protected by vegetation

not so far as to erode the opposite bank. To safeguard against potential damage, begin slowly. Use gentle angles, and keep to short spans. Check the site frequently during the winter, and be prepared to adjust the deflector if problems develop.

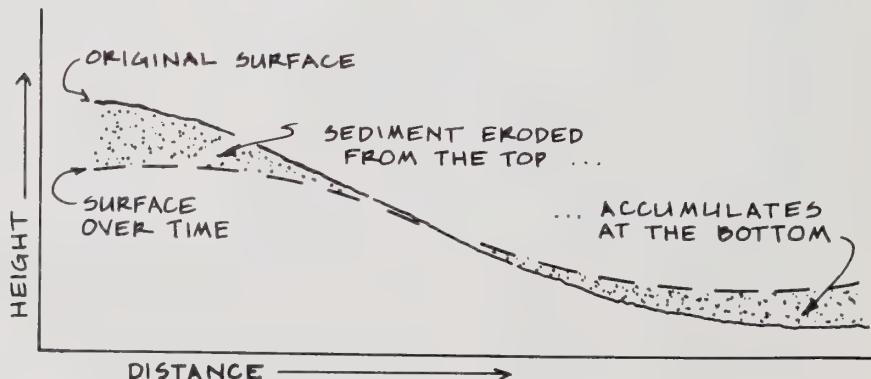
Straightening the Channel

Channel straightening requires realigning the stream with heavy equipment. It should be considered only in extreme cases when none of the other remedies are practical, and then only with sound, professional advice.

2. DOWNCUTTING

The laws of gravity dictate that soil and rock move downhill. Upper reaches of streams cut deeper into the hillsides, sending sediment to accumulate at the lower reaches. Eventually, over long spans of time, all streams will reach a gentle, even gradient over their entire length. As with meandering, this natural process has been speeded up by human activity in the watershed, which increases the rate of storm runoff beyond the stream's capacity to handle it safely.

Downcutting in streams is the same process as headcut movement in a gully (see Chapter 3) and the same measures work to stop it but on a larger scale. Checkdams in streambeds are usually referred to as grade stabilization structures. Like smaller dams, they raise or secure the level of the channel and prevent toecutting of the banks and



The "flat rule"

subsequent sloughing. Grade stabilization structures need to be engineered. Concrete barriers submerged below the stream bottom or compacted earth dams are frequently used.

3. SURFACE AND SUBSURFACE FLOW

Excess surface runoff and subsurface water flowing from streambanks can worsen existing bank erosion and occasionally be a primary cause. Surface runoff gullies the bank face, undermining whatever armor has been placed or planted there to protect the bank. Inordinate amounts of subsurface flow can saturate banks and make them far more vulnerable to outside-curve erosion and downcutting.

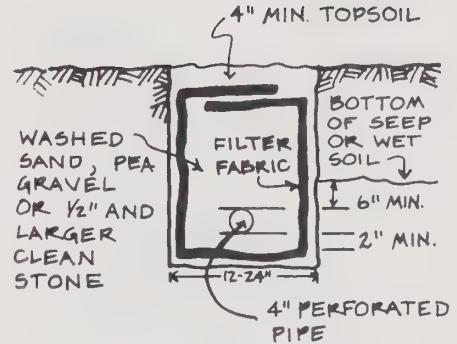
Surface and subsurface flow can often be controlled at the source. Roofs, foundation drains, road grading and over-irrigation are common sources of excess flow. If the source cannot be eliminated, berms can trap surface flow and subsurface drains can intercept ground water before they reach vulnerable banks. Remember to redirect the captured flow to a well-protected, nonerodible point.

4. DEBRIS

Fallen trees, washing machines, shopping carts, old cars and other debris can force streamflow into banks and cause erosion.

The obvious repair is to remove the obstruction; but before you do that, take a good look at the site. Woody debris, especially, can provide excellent fish habitat and is a natural component of most stream systems. You should consider trimming the tree or logs to reduce the bank erosion, while leaving the main trunk and root wad intact, or moving the obstruction out of the main flow and securing it to the bank. Don't ever modify an obstacle so that it is lighter or can move more easily, and then leave it in the channel. It will wash downstream and pester your neighbor. Either make sure it is stable, anchor it or remove it completely.

If sediment has accumulated behind the obstacle, removing it may have the same effect as ripping out a checkdam in a gully. SCS or the California Department of Fish and Game can help you decide how to handle a debris obstacle.



Subsurface drain





Livestock Areas



Horses, sheep, cattle and other livestock—even llamas—can affect erosion in many ways. Concentrated in a small area, livestock can completely denude the soil surface, exposing it to sheet and rill erosion. The weight of the animals can compact the soil to concrete-like hardness, which in turn increases the speed of runoff and activates gully and streambank erosion lower in the watershed. Compaction can also occur in large pastures if the land has been heavily grazed for many years.

If you notice that your springs dry up sooner than they used to or your wells give less water, soil compaction may be the culprit. Runoff will opt for the easier route and flow over the hard surface, instead of soaking slowly through vegetation and loose soil to replenish the groundwater.

Livestock changes the vegetation by selectively eating certain species, giving other hardier, less-palatable plants room to flourish. Some plants, such as oaks and certain grasses, cannot tolerate soil compaction around their root zones and eventually die out unless protected. The length of grass roots corresponds to the length of the leaves above the soil; if the grass is never allowed to grow tall, its roots will remain short and provide less soil protection.

Larger animals can cause mechanical damage to stream and gully banks by walking on them and crushing or eating the new vegetation that might stabilize the banks.

Yet for thousands of years, grazing animals coexisted in harmony with the same soil and water conditions we have today. The big change is in the number of animals now on the land and the amount of time they stay in one place. Some horses spend their entire lives in a 1000-square-foot paddock, whereas a herd of elk might have moved in, eaten everything in sight, and then left for a year or more.

Reducing erosion caused by livestock is a twofold process: protecting vulnerable areas, and attempting to make the most use out of soil fertility, plant cover and water while allowing all these resources to replenish themselves. The latter process requires a tremendous knowledge of the land and livestock needs, as well as a long-range commitment. In this handbook, we will briefly discuss some methods for both aspects, protection and grazing management. For more information, contact your local SCS field office or university extension service.

Arrange paddocks along slope contour separated by buffer strips. Such an arrangement will encourage the confined animal to move along the contour instead of up and down the slope. Runoff is allowed to flow only a short vertical distance over exposed soil before it is slowed and filtered by the grass buffer strip.

Surface poorly drained paddocks with gravel. A gravel layer will protect the soil surface from continual disturbance as well as keep your animal's feet dry!

PAUL SHEFFER





Paddocks arranged on slope contour

Create a vegetative filter between livestock and flowing water.

Grass is the best filter, but woody plants will also slow flow and trap sediment, as well as hold banks in place and provide wildlife habitat. The width of the buffer strip depends on the slope, number of animals and drainage area. For filtering dairy wastes from heavily concentrated animals, a minimum width of 300 feet is recommended. However, for rangeland and corrals with few animals, widths of 50 feet and greater are usually sufficient. Your local SCS field office can determine the appropriate filter width for your specific conditions.

The filter must be protected from grazing. If the filter is grass, livestock can be allowed in for a short period after the seed has set, but while the grass is still green and palatable to reduce the fire hazard and reinvigorate the perennial roots by removing the dead growth.

Keep livestock out of vulnerable areas.

These include active or suspect landslides, active gullies, eroding stream channels and newly planted areas. Excluding small areas of rangeland from livestock has other benefits

besides erosion control. Trees allowed to grow to maturity on the edges of the enclosure provide shade for livestock and cover for deer, quail and other wildlife.

Provide alternate water and salt sources.

Increasing the number of places where livestock have access to water and salt spreads them over the available range and reduces the compaction and overgrazing near existing water sources. Separating the water and salt blocks will spread the animals more evenly.

Seed and fertilize pastures.

Increasing the quality and density of vegetation will slow runoff, allowing it to percolate down to replenish groundwater supplies, and reduce sheet and rill erosion.

Install sediment basins.

As a last-ditch effort, sediment basins can be installed to clean runoff before it enters the stream system. This is not only a "Band-Aid," however, but a very loose one. Sediment basins must be regularly maintained; once they fill, they are no longer effective. The soil removed must then be stored or respread and stabilized so it doesn't wash right back in.

The SCS can provide detailed construction specifications for basins of various sizes.

Modify your grazing system.

Grazing systems manipulate the number of animals in a given area, how long and when they graze there, and the amount of forage and available water to provide maximum, sustainable use of the land. Most grazing systems require fencing and regular rotation of livestock from pasture to pasture. Some call for an even distribution of animals over the range; some, such as the Holistic Method, call for the intense use of small areas of land for a short time. Probably the best grazing systems combine scientific research with the landowner's own specific knowledge and needs. References for more information are listed in Chapter 10.

No-till and minimum-till cultivation.

In no-till cultivation of hay and silage crops, the new seed is planted through the old stubble. The land is not plowed, and

LIZA PRUNUSKE



Grass filter between horse paddock and winter swale

therefore the soil is never exposed to winter rains. A special seed drill is used that injects the seed, fertilizer and frequently an herbicide all at one time.

The field is lightly plowed in minimum-till cultivation, enough to break the soil but not to remove all the stubble. With either method, the field may have to be clean-tilled, with all stubble plowed in, approximately every three years for weed control. Detailed information is available from the SCS.

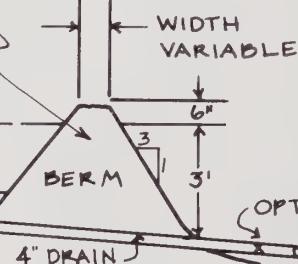
No-till and minimum-till cultivation are highly recommended for sloped fields, especially those with recurring rill erosion. Sheet and rill erosion can be deceiving. 1/4 inch of soil lost evenly over a 40 acre field yields 900 tons of earth or 90 dumptruck loads washed into the nearest stream.

Sediment basin

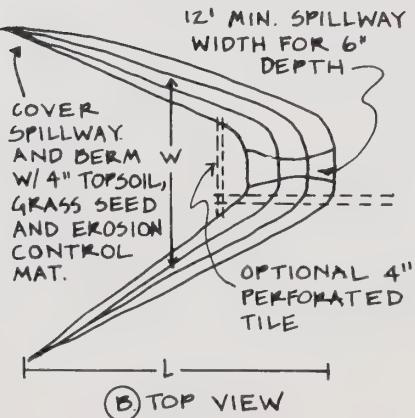
(A) SIDE VIEW

OPTIMUM SIZE OF TRAP AREA ($W \times L$)
IS 3,500 SQ. FT. FOR UP TO $1/2$ ACRE DRAINAGE AREA

FORM BERM FROM
EXCAVATED
TOPSOIL



12' MIN. SPILLWAY
WIDTH FOR 6"
DEPTH





New Construction

Building anything, whether a standing structure, a road, a parking lot or a playground, almost always involves removing vegetation and changing drainage patterns—actions which can provoke and accelerate soil loss. Some counties have enacted strict guidelines to reduce erosion at construction sites. If your county does not have specifications available, both the Soil Conservation Service and Reference 18, the Association of Bay Area Governments' (ABAG) *Manual of Standards for Erosion and Sediment Control Measures*, can provide general guidelines and specifications. (See Chapter 10.) Following are some commonly used techniques to protect the soil during and immediately after construction.

Timing

Construction which moves soil, disturbs vegetative cover or requires use of unsurfaced roads should be completed before the winter rainy season; in northern coastal California, October 1 is the standard date used to mark the official end of dry weather. If unfinished work must be held over until spring, exposed soil should be protected and sediment trapped before leaving the site as described below.

Conserving Existing Vegetation

Wherever possible, plants already growing on the site should be spared, unless the cleared area is to be immediately replanted or landscaped. Even then, be cautious about removing vegetation. It may take many years for new plantings to duplicate the character and sturdy root systems of the on-site trees and shrubs. Thinning groves of mature trees, especially on ridgetops, may make the remaining trees more susceptible to windthrow. And remember that changing

LIZA PRUNUSKE



Trees left standing at construction site



Grass growing through excelsior mat

vegetation changes the wildlife use of an area. If you have grown to enjoy the flocks of warblers migrating through your new piece of property every fall, don't expect them to return after you have removed all the undergrowth.

Where construction calls for mass disturbance of wildland vegetation, such as large cut and fill slopes, the native plant community should be restored through revegetation. Large-scale revegetation projects differ from home or commercial landscaping in that the plants receive minimal maintenance. The area is overplanted with the expectation that some of the plants will die. Plants are grown from seeds or cuttings collected on or near the construction site so that they will be well-adapted to specific soil and weather conditions at the site and thus have a better chance of surviving with little attention. Since it takes one to two years to grow a plant big enough to install, revegetation projects should be planned well in advance of actual construction.

Seeding and Mulching of Bare Areas and Spoils Piles

All bare soil, including temporary spoils piles, should be buttoned down with grass seed and mulch. Annual grains, such as ryegrass, oats and barley, are frequently used as one-time winter cover because they are relatively inexpensive and reseed poorly. If you desire permanent cover, consult the SCS or a local seed dealer for long-term seeding mixes. Fertilizer should be used to ensure rapid, vigorous growth; 500 pounds per acre of 16-20-0 fertilizer is a common prescription.

The seed and fertilizer should be raked in and protected with a mulch, such as straw, wood fiber, jute or excelsior mat, as specified under headcut repair in Chapter 3. Loose mulch materials must be held in place with jute or polypropylene netting on slopes greater than 2:1. In extremely steep or windy areas, hydroseeding may be necessary. Hydroseeding is a mechanical process of blowing a slurry of seed, fertilizer, mulch and a tackifier on the slope.

Temporary Sediment Traps

A row of strawbales or a filter fabric fence placed below an area of exposed soil will intercept and filter runoff where seeding and mulch are not feasible. They can also be used in combination with seeding and mulch on especially erodible sites. The drainage area above each row should be less than

1 acre and have a slope no greater than 2:1. They are intended to be used for slopes; checkdam specifications should be followed in drainages.

The strawbales should be installed in the same manner as described for strawbale checkdams in Chapter 3 except that the ends are left freestanding, not keyed into a bank. Filter fabric silt fences come with built-in sleeves that slip over fence posts. They should be installed according to manufacturer's instructions. Both types of temporary trap must be checked regularly during the winter and repaired if necessary.

Sediment Basins

Sediment basins, described in Chapter 7, are used to trap sediment from bare areas larger than 1 acre until the construction site is permanently stabilized. In order to remain effective, they must be cleaned out when full and the sediment stored where it cannot again wash away. A series of smaller basins is recommended over a single large one because they are less likely to fail, easier to maintain and less expensive to construct.

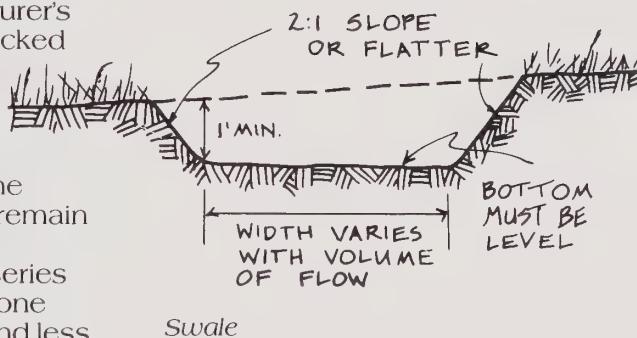
Surfacing Heavy Traffic Areas

If construction must continue into the rainy season, roads and parking areas that are used frequently and/or for heavy equipment transport should be protected with gravel. In poorly drained areas, the gravel should be placed over a filter fabric blanket.

Directing Surface Runoff Through Non-Erodible Channels

Swales are used to intercept runoff before it reaches the construction site or to redirect stormflow through the site. For drainage areas less than 5 acres, the swales should be lined with grass. If the slope of the swale exceeds 5%, the grass seed should be covered with an erosion control netting, such as jute or excelsior mat. Consult a professional engineer if the drainage area is greater than 5 acres.

Both the SCS and the ABAG manual (Reference 18) have detailed specifications for lining and constructing swales based on soil type, drainage area and speed of flow.





Wildlife

Halting gullies and repairing road washouts do more than keep soil on the ground and out of our waterways—erosion control helps wildlife in both immediate and long-term ways. Examples of quick benefits include the creation of a woody oasis for birds one season after planting willows in a pasture gully, and the instant shade and protection from predators provided for fish by wing deflectors.

Long-term soil stabilization has less spectacular but even more important effects on wild animals. Let's take one example—repairing a streambank failure. At the site, trees and shrubs still clinging to the top of the bank are rescued from falling into the channel. If the bank must be sloped back, the trees on the very edge will be lost, but those further back are protected from advancing erosion. Along with the plants, nests, perches, shelter and food sources are also saved. The leaves falling into the stream give cover and food for the small aquatic creatures that fuel the stream's food chain.

Downstream, the reduced amount of sediment means less meander-type erosion. Pools remain deep and cool all summer, spawning gravels stay clean and water circulates freely through marshes. Healthy stream systems do need some sediment to replace what is flushed out in stormflows and to bring in minerals and organic matter, but rarely is too little sediment a problem in developed watersheds.

Considering wildlife needs when you repair an erosion site can help your conservation dollar go farther. If you want to target a specific animal, say silver salmon, you might choose a bank repair that would combine numerous small, underwater crannies with overhanging vegetation, riprap interplanted with willow, for example. Chapter 10 lists several agencies where you can get information and advice on enhancing wildlife habitat.



Where To Get More Help

ORGANIZATIONS

The following organizations provide information and, in some cases, on-site assistance with identifying and repairing erosion problems.

Resource Conservation Districts: Most California counties have one or more RCD's. You can get in touch with them through your local Soil Conservation Service or the California Association of Resource Conservation Districts, 3830 U Street, Sacramento, CA 95817.

USDA Soil Conservation Service (SCS): SCS field offices are located wherever there are RCD's. You can find the one nearest you in the U.S. Government pages of your phone directory. If you need advice on erosion control, the SCS should be your first stop. The SCS can provide technical specifications; information about possible financial assistance from government cost-sharing programs; soils information; on-site advice on selecting an appropriate repair; and help with finding a contractor, consultant or unusual materials. They usually have well-stocked libraries of their own publications and other erosion control references. Local offices have available to them geologists, engineers, wildlife biologists, agronomists and a host of other specialists at the service of the public.

US Geological Survey (USGS): Part of the Department of the Interior, USGS studies and inventories geological and related resources. They have a wealth of maps, aerial photos, infrared photos and many other useful land management tools. Write to Public Inquiries Office, USGS, 504 Custom House, 555 Battery Street, San Francisco, CA 94111, for more information.

US Fish and Wildlife Service (USFWS): Also part of the Department of the Interior, USFWS can provide information on enhancing and protecting wild animal habitat. In northern California, contact U.S. Fish and Wildlife Service, Room E-1803, 2800 Cottage, Sacramento, CA 95825.

US Forestry Service (USFS): Another Service of the Department of Agriculture, USFS has done much pioneering research on erosion control methods. They have many fine publications available describing erosion problems and practical ways to fix them. Local offices can be found in or near the National Forests, and a regional office is located at 630 Sansome Street, San Francisco, CA 94111.

US Army Corps of Engineers (USACE): The Corps is in charge of waters of the U.S., including bays, harbors and navigable streams. They require permits for work done in waters under their jurisdiction. To find out if you need a permit, send a description of your proposed project to District Engineer, U.S. Army Corps of Engineers, Attn: Regulatory Branch, 211 Main Street, San Francisco, CA 94105.

California Department of Fish and GAME (CDFG): CDFG has wardens and field biologists working throughout the state. Besides issuing permits for streambank alterations, they can provide practical advice on how to make your repairs effective in both reducing erosion and helping wildlife. Like the SCS, they will come to your site to give you on-the-spot help. Northern coastal California through Mendocino County is served by the Region 2 office, Box 47, Yountville, CA 94599; north of Mendocino County write to the Region 1 office, Box 1480, Redding, CA 96001.

California Coastal Conservancy: This organization funds programs to purchase and protect coastal resources and make them more accessible to the public. For more information, write to Suite 1100, 1330 Broadway, Oakland, CA 94612.

California Coastal Commission: The Coastal Commission regulates development and land use within coastal zones. If you live within their jurisdiction, check with your county planning department or the Commission's Northern California Office at 631 Howard Street, San Francisco, CA 94103, (415) 543-8555, to see if you need a permit for your erosion control project. Large earth sediment dams, road reconstruction and stream diversion are likely candidates for permits.



California Division of Mines and Geology: This group offers a goldmine of maps and reports on landslides and related geological features that both affect and help explain erosion problems. A list of publications and prices is available from the Department of Conservation, Division of Mines and Geology, Publications and Information Office, P.O. Box 2980, Sacramento, CA 95812, (916) 445-5716.

University Cooperative Extension Service: This service has many useful publications on everything from crop selection to feeding wildlife, controlling pests and bread baking. Extension agents do make site visits to help with specific problems. They have offices in most counties, often listed in the County Government section under "Farm Advisor."

County and City Public Works and Planning Departments: These are good starting places to find out about local regulations and permits. They are also good sources of aerial photographs, resource inventories and maps, regional know-how and references for additional information.

SELECTED REFERENCES

The following is by no means an exhaustive list, but it should get you started.

General

1. *Bioengineering for Land Reclamation and Conservation*, by Hugo Schiechtl. 1980. University of Alberta Press, Edmonton, Alberta. A creative and historic look at using biotechnical methods, full of intriguing methods. Much of the source material is European.

2. *Biotechnical Slope Protection and Erosion Control*, by Donald H. Gray and Andrew T. Leiser. 1982. Van Nostrand Reinhold, New York, NY. An excellent source of theory, repair ideas and designs.

3. *Conquest of the Land through 7,000 Years*, by W.C. Lowdermilk. 1953. Revised 1975. USDA Soil Conservation Service, Ag. Info. Bull. No. 99. A delightfully written and fascinating (though sobering) account of how soil erosion has eradicated many ancient cities, and even entire civilizations.

4. *The Earth Manual*, by Malcolm Margolin. 2nd ed. 1986. Houghton Mifflin, Boston, MA. Available in many bookstores,

this is a loving and accessible book on managing wild land. It includes chapters on wildlife, planting and erosion control.

5. *Handbook of Best Management Practices for the 9 Bay Area Counties*, by G.M. Kennedy and H.T. Shogren. 1977. Council of Bay Area Resource Conservation Districts, 5552 Clayton Road, Concord, CA, (415) 672-6522. Specifications on just about everything that affects water quality from dikes to firebreaks to grassed waterways.

6. *Technical Specifications for Hand-Labor Erosion Control Methods*, by William Weaver. Revised 1985. Unpublished report available from Redwood National Park, Arcata, CA 95521. Practical, step-by-step directions for seeding, revegetation, checkdams and many other techniques.

Gullies (See General also.)

7. *Gully Development and Control: The Status of Our Knowledge*, by Burchard H. Heede. 1976. US Forest Service. Research Paper RM-169. Rocky Mountain Forest and Range Exp. Station, Ft. Collins, CO 80521. This is one of many publications by Heede based on his extensive experiments on repairing gullies. Contains specifications for many types of checkdam, plus extensive discussion of gully formation.

8. *Handbook of Erosion Control in Mountain Meadows*, by Charles J. Kraebel and Arthur F. Pillsbury. 1934. Reissued 1980. US Forest Service. Clear, down-to-earth explanations of how gullies grow and how to repair them. Includes specification for willow sprigging and wattling.

9. *Guidelines for Gully Control*, by Steve Singer. 1980. Available from the Santa Cruz County RCD, Suite A, 323 Spreckles Drive, Aptos, CA 95003.

Landslides (See General also.)

10. *Bibliography of U.S. Maps and Reports*, by C. Algier and E. Brabb. 1985. USGS Open File Report 85-585. Available for \$18.50 from USGS, Box 25286 Federal Ctr., Denver, CO 80225.

11. *Geology for Planning in Sonoma County*, by M.E. Huffman and C.F. Armstrong. 1980. CA Division of Mines and Geology, Special Report 120. Available for \$13.50 from Division of Mines and Geology, P.O. Box 2980, Sacramento, CA 95812.

12. *Geology and Geologic Hazards of the Novato Area, Marin County*, by S.J. Rice and G.B. Chase. 1973. CA Division of Mines and Geology. Preliminary Report 21. Available for \$7.00. (See above address.)
13. *A Guide for the Control of Landslides*, by Steve Singer. 1980. Revised 1982. Available from the Santa Cruz County RCD, Suite A, 323 Spreckles Drive, Aptos, CA 95003.
14. *Landslide Hazards in the Southeastern Part of the Petaluma Dairy Belt, Sonoma County, California*. 1986. CA Division of Mines and Geology. Open File Report 86-5 SF. Available for \$5.00. (See above address.)
15. *Landslide Inventory and Susceptibility Mapping in California*, by F. Taylor and E. Brabb. 1986. USGS Open File Report 86-100. The "Rosetta Stone" of landslide information in California. Available from USGS, Box 25286, Federal Ctr., Denver, CO 80225.

Roads

16. *Building Water Pollution Control into Small Private Forest and Ranchland Roads*, by A.C. Darrach, W.J. Sauerwein, C.E. Hally. 1981. USDA Forest Service and Soil Conservation Service. R6-S&PF-006-1980. The granddaddy of the *Mendocino Road Building Guide*. Comes in a small, handy size, perfect for taking out in the field. Available from the USDA Forest Service, Attn. Range and Watershed Management, Box 3623, Portland, OR 97208.
17. *Road Building Guide for Small Private Roads*, by Robert A. Dellberg. 1982. Available from the Mendocino RCD, 405 Orchard Ave, Ukiah, CA 95482, for \$5.00 for single copies. An indispensable resource for constructing and maintaining ranch and fire roads.

New Construction

18. *Manual of Standards for Erosion and Sediment Control Measures*, by the Association of Bay Area Governments (ABAG). 1981. Available from ABAG, P.O. Box 2050, Oakland, CA 94604, for \$20.00. Contains many standard specifications and procedures.



Wildlife (See General also.)

19. *American Wildlife and Plants: A Guide to Wildlife Food Habits*, by A.C. Martin, H.S. Zim and A.L. Nelson. 1961. Dover, New York, NY. A handy guide to what birds and mammals eat.
20. *Fish Habitat Improvement Handbook*, by Monte E. Seehorn. 1985. USDA Forest Service. Technical Publication R8-TP 7. Lots of easy-to-follow instructions. Just remember they are designed for southeast US, which has milder stormflows than coastal California.
21. *Stream Enhancement Guide*, by British Columbia Ministry of Environment. 1980. B.C. Minister of Environment, Fish and Wildlife Branch, Vancouver, B.C., Canada. Another excellent guide for improving fish habitat.

Plants

22. *Growing California Native Plants*, by Marjorie Schmidt. 1980. UC Berkeley Press, Berkeley, CA. Oriented more for fitting native plants into your garden than towards large-scale revegetation.
23. *Groundcover: A Planting Guide for Erosion Control in Santa Cruz County*, by Steve Singer. 1980. Revised 1983. Available from the Santa Cruz County RCD, Suite A, 323 Spreckles Drive, Aptos, CA 95003. Includes description of many plants, seeding and fertilizer rates, a guide to selecting mulches and clear instructions.
24. *Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States*, by the USDA Soil Conservation Service. 1969. Agricultural Handbook #339. Available from the Superintendent of Documents, US Government Printing Office, Washington, DC 20402. Thorough descriptions and illustrations.
25. *Direct Seeding Woody Plants in the Landscape*, by Frank J. Chan, R.W. Harris and A.T. Leiser. 1972. University of California Agricultural Leaflet #2577, Davis, CA 95616.

Soils

26. Soil Surveys of most counties are available from the Soil Conservation Service. These map different soil types and describe their properties in relation to construction, septic systems, plant growth, erodibility, wildlife habitat, recreational use and many other factors.

Range Management, Grazing Systems

27. Center for Holistic Resource Management, P.O. Box 7128, Albuquerque, NM 87194. A newsletter, question-and-answer pamphlet and other information are available. Holistic Resource Management involves much more than range management; it incorporates basic biological and mineral cycles with the landowners goals and human resources to use land effectively without abusing it.

28. *Preliminary Guidelines for Managing California's Hardwood Rangelands*. 1985. California Cooperative Extension Service. Publication 21413. \$5.00. Check your local extension office for availability.

29. *Specialized Grazing Systems: Their Place in Range Management*. USDA Soil Conservation Service, TP-152. Check local SCS field office for availability.

30. *The XXX Ranch: Managing Range for Ecology and Economy*, by John Merrill. 1983. USDA Soil Conservation Service. Chapter in 1983 *Yearbook of Agriculture*. Copies for sale from the Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

Glossary

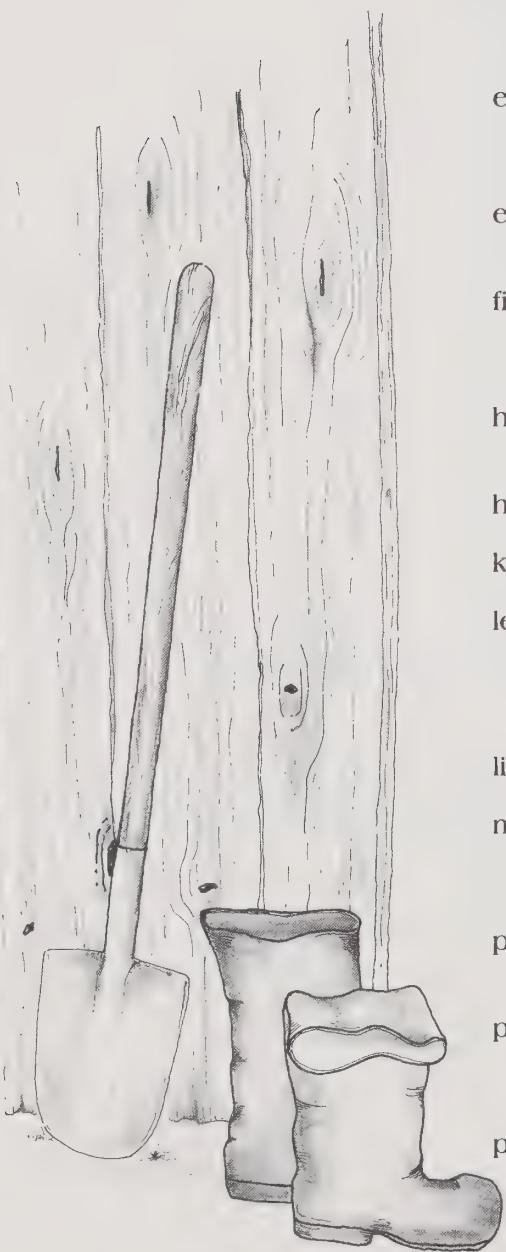
angle of repose: the slope at which a given soil will stay in place

annual grass: a grass that dies every year. All new growth comes from the previous year's seed.

checkdam: a structure built across a watercourse to trap sediment and slow erosion

deadmen anchors: logs or other types of piling set into a bank perpendicular to a retaining wall. Secured to the wall and then covered with soil, they help hold the wall in place.

desertification: the process of loss of vegetation and subsequent erosion that turns forests or grasslands into desert



effective height: in a dam, the height from the bottom of the channel to the spillway. The effective height sets the uppermost level at which water and sediment will accumulate behind the dam.

energy dissipator: an apron of rocks, logs, concrete baffles or other material that slows down water flowing through a culvert, ditch or over a dam, and thereby reduces its erosive force

evapotranspiration: the process by which plants take in water through their roots and then give it off through their leaves as a by-product of respiration

filter fabric: a polypropylene textile used to keep soil separate from water. Comes in many different forms and used for constructing roads, lining ponds, and many erosion control projects

headcut: a break in slope at the top of a gully or section of gully that forms a "waterfall" which in turn causes the underlying soil to erode and the gully to expand uphill

herbaceous vegetation: any plants, such as grasses or clovers, that do not develop a woody stem and twigs

keyway, key: the notch excavated into the sides of a gully or stream to anchor a checkdam or other structure

legume: a plant in the pea family including clovers, lupines, alfalfa and even trees such as locusts and acacias. Legumes are characterized by nodules on their roots formed by soil microorganisms which convert nitrogen in the air to a form plants can take up through their roots.

lifts: layers of loose soil. Used to specify how much loose soil should be laid down at a time before it must be compacted

mulch: a substance placed over the soil surface to inhibit weed growth, conserve moisture and in some cases, prevent heat loss. Examples include straw, wood chips and plastic sheets.

perforated riser: a pipe with regularly spaced openings which is installed upright in a settling basin. It allows water to enter as sediment builds up.

perennial grass: a grass that lives for more than one growing season. All visible leaves die back each year, but the roots send out new growth in spring. Perennial grass roots are typically deeper than those of annual grasses.

piping: the process by which water forces an opening around a supposedly sealed structure, such as a checkdam. As water flows through, the opening usually grows larger.

rebar: steel rod used primarily for reinforcing concrete

rill erosion (rilling): a series of miniature gullies, less than 1 foot deep, occurring on a slope parallel to the direction of runoff. The smallest visible amount of rill erosion indicates that at least 15 tons of soil per acre are being lost annually.

riprap: heavy stones used to protect soil from the action of fast-moving water. Minimum size is usually 12" x 12" x 6" with a specific gravity of 2.5 or greater.

sheet erosion: the loss of thin, sometimes microscopic, layers of soil evenly from a slope

soil cement: a mixture of sandy and gravelly soil with 6 to 10% cement, well mixed and compacted, used to form a stable base. Soil cement is not strong enough for surfaces subjected to continuous wear, such as spillways or wing deflectors.

spillway: the place at the top of a dam or checkdam over which water flows

swale: small depressions, natural or man-made, that carry water only after a rainfall.

toe: the base or lower edge, as of a checkdam or streambank

trash rack: a barrier placed at the upstream end of a culvert to trap debris but still allow water to flow through

watershed: all the land that drains into a particular stream, river or larger body of water

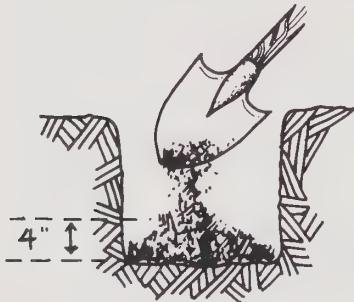
Appendix

PARTIAL LIST OF WOODY PLANTS MARIN COUNTY, CALIFORNIA

The following trees and shrubs grow in Marin and neighboring counties. The best clue for selecting wild plants is the existing vegetation community at the planting site. If coast live oaks, for example, are flourishing near your site naturally, they would be a good choice for a successful planting project. The

Planting container stock

1. DIG HOLE 1½ TIMES AS DEEP AND TWICE AS WIDE AS CONTAINER.
2. ADD WATER TO HOLE AND LET DRAIN.
3. PLACE 1 SLOW RELEASE FERTILIZER (OR OTHER FERTILIZER) IN THE BOTTOM OF HOLE. FILL BOTTOM 4" WITH 50/50 MIXTURE OF LOOSE SOIL AND ORGANIC MIXTURE.



4. CUT CAN AND GENTLY REMOVE PLANT. PRUNE ANY ENCIRCLING OR KINKED ROOTS.

5. PLACE PLANT IN HOLE AND FILL ½ WAY W/ PLANTING MIXTURE. BE SURE THAT CROWN OF PLANT LIES ABOVE GRADE. TAMP MIXTURE, ADD WATER AND LET DRAIN.

Native Plant Society has chapters throughout California and can help you find a nursery and propagate wild plants yourself.

Riparian Plants

Lower Bank

Trees

California bay (*Umbellularia californica*): California boxelder (*Acer negundo*)—grows fast, then breaks apart: Fremont cottonwood (*Populus fremontii*): Hinds walnut (*Juglans hindsii*): Oregon ash (*Fraxinus oregonia*): Red alder (*Alnus oregonia*):

Shrubs

Red elderberry (*Sambucus callicarpa*): California blackberry (*Rubus ursinus*): Himalaya berry (*Rubus discolor*)—invasive, non-native species: Poison oak (*Rhus diversiloba*): Salmon berry (*Rubus spectabilis* var. *franciscanus*): Spice bush (*Calycanthus occidentalis*): Willow (*Salix* sp.) many species: Snowberry (*Symporicarpos rivularis*): Western azalea (*Rhododendron occidentale*):

Riparian Plants

Upper Bank

Trees

Big-leaf maple (*Acer macrophyllum*): California nutmeg (*Torreya californica*): Coast live oak (*Quercus agrifolia*): Douglas fir (*Pseudotsuga menziesii*): Redwood (*Sequoia sempervirens*): Valley Oak (*Quercus lobata*):

Shrubs

Coffeeberry (*Rhamnus californica*): Dogwood (*Cornus californica*): California hazelnut (*Corylus californica*): Blue elderberry (*Sambucus coerulea*):

Upland Plants

Trees

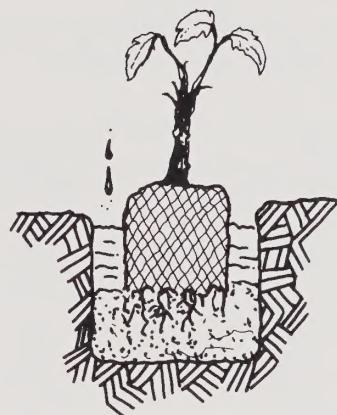
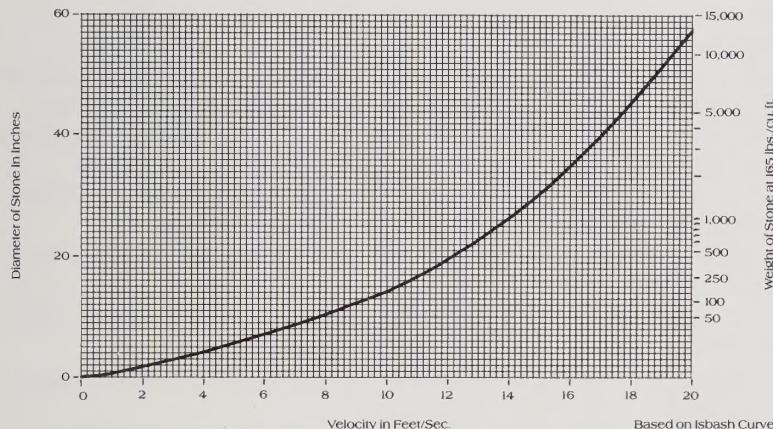
Coast live oak: Valley oak: Black oak (*Quercus Kelloggii*): Canyon live oak (*Quercus chrysolepis*): California bay: Tan oak (*Lithocarpus densiflora*): Douglas fir: Redwood: California buckeye (*Aesculus californica*): Madrone (*Arbutus Menziesii*):

Shrubs

Coffeeberry: Coyote brush (*Baccharis pilularis*): Ocean spray (*Holodiscus discolor*): Blue elderberry: California sagebrush

(*Artemisia californica*): Manzanita (*Arctostaphylos* spp.) check with nursery for correct species for your site; Ceanothus (*Ceanothus* spp.) check with nursery for correct species for your site.

DETERMINING RIPRAP SIZE



6. FILL THE HOLE TO TOP BEING CAREFUL NOT TO COVER THE CROWN. TAMP DOWN FIRMLY. USE ADDITIONAL SOIL TO MAKE A WATERING BASIN. BE SURE THAT WATER DRAINS AWAY FROM THE STEM. WATER THOROUGHLY AND CONTINUE TO WATER DEEPLY AT INFREQUENT INTERVALS UNTIL PLANT IS WELL ESTABLISHED.

Maximum weight of stone required (lbs.)	Minimum and maximum range in weight of stones (lbs.)	Weight range of 75 percent of stones (lbs.)
150	25- 150	50- 150
200	25- 200	50- 200
250	25- 250	50- 250
400	25- 400	100- 400
600	25- 600	150- 600
800	25- 800	200- 800
1000	50-1000	250-1000
1300	50-1300	325-1300
1600	50-1600	400-1600
2000	75-2000	600-2000
2700	100-2700	800-2700

Notes:

1. The velocity is the speed of the current within ten feet of the bank.
2. If debris impact is a major factor, double the stone weight.

Source: USDA Soil Conservation Service Engineering Field Manual

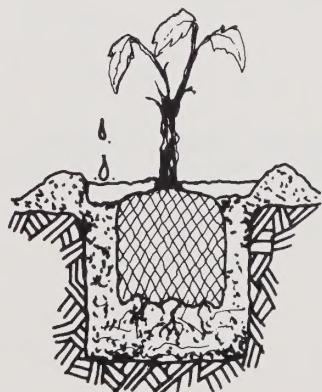
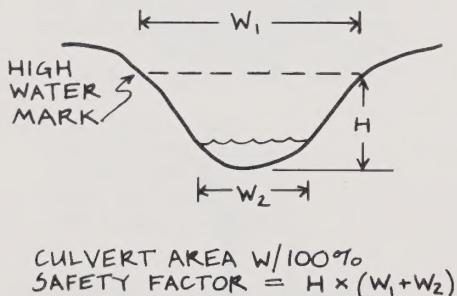


Table 1
Sizes of Round Pipe Needed
For Areas of Waterway

Area Square Feet	Diameter Inches
1.80	18
3.10	24
4.90	30
7.10	36
9.60	42
12.60	48
15.90	54
19.60	60
23.80	66
28.30	72
33.20	78
38.50	84
44.20	90

Figure A.



CULVERT SIZING

Source: Dellberg, R.A. 1982. Road building guide for small private roads. Mendocino County Resource County Conservation District. Ukiah, CA.

Culverts need to be large enough to meet flood-stage requirements, rather than just normal flow. Currently, the 25-year storm frequency is considered satisfactory for design purposes for the class of road under consideration. Several formulas, special tables, and other means are used to determine culvert sizes. A simple method called the Hasty Method may be used. This method uses measurements taken in the stream channel to estimate the size of culvert needed including a 100 percent safety factor. To use this method do the following:

1. Measure the width (W_2) of the channel at the bottom. See Figures A.
2. Measure the width (W_1) of the channel at the normal high water mark.
3. Measure the height (H) from the channel bottom to the normal high water mark.
4. Add the widths and multiply by the height. This doubles the cross sectional area to give a 100% safety factor.
5. See Table 1 for size of culvert needed.

Example:

Waterway end area

$$\begin{aligned}
 W_1 &= 3 \text{ feet} \\
 W_2 &= 1 \text{ foot} \\
 H &= 2 \text{ feet} \\
 \text{sq. ft.} &= H \times (W_1 + W_2) \\
 &= 2 \times (3 + 1) \\
 &= 8 \text{ sq. ft. with 100\% safety factor} \\
 &\quad (W_1 \text{ \& } W_2 \text{ are added so this produces 100\% safety factor})
 \end{aligned}$$

Culverts are usually available in 6" diameter increments above 18". Table 1 states that a 36" culvert has an area of 7.1 feet and a 42" culvert satisfies the conditions of this example.

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